limited gamut 2614 may be defined to ensure that the colors within the gamut 2614 can be consistently produced by all light sources 300 across a wide range of lighting units 102, even accounting for lower quality light sources 300. Thus, such a program can improve consistency of lighting units 102 from unit to unit.

5

The photopic response of the human eye varies across different colors for a given intensity of light radiation. For example, the human eye may tend to respond more effectively to green light than to blue light of the same intensity. As a result, a lighting unit 102 may seem dimmer if turned on blue than the same lighting unit 102 seems when turned on green. However, in installations of multiple lighting units 102, users may desire that different lighting units 102 have similar intensities when turned on, rather than having some lighting units 102 appear dim while others appear bright. A program can be stored on a data storage facility 3700 for use by the processor 3600 to adjust the pulses of current delivered to the light sources 300 (and in turn the apparent intensity of the light sources) based on the predicted photopic response of the human eye to the color of light that is called for by the processor 3600 at any given time. A lookup table or similar facility can associate each color with a particular intensity scale, so that each color can be scaled relative to all others in apparent intensity. The result is that lighting units 102 can be caused to deliver light output along isoluminance curves (similar to topographic lines on a map) throughout the gamut 2614, where each curve represents a common level of apparent light output of the lighting unit 102. The program can account for the particular spectral output characteristics of the types of light sources 300 that make up a particular type of lighting unit 102 and can account for differences in the light sources 300 between different lighting units 102, so that lighting units 102 using different light sources 300, such as from different vendors, can nevertheless provide light output of consistent intensity at any given color.

A control interface 4900 may be provided for a lighting unit 102. The interface can vary in complexity, ranging from having minimal control, such as "on-off" control and dimming, to much more extensive control, such as producing elaborate shows and

effects using a graphical user interface for authoring them and using network systems to deliver the shows and effects to lighting units 102 deployed in complex geometries.

Referring to Fig. 27a, it is desirable to provide a light system manager 5000 to 5   manage a plurality of lighting units 102 or light systems 100.

Referring to Fig. 27b, the light system manager 5000 is provided, which may consist of a combination of hardware and software components. Included is a mapping facility 5002 for mapping the locations of a plurality of light systems. The mapping 10   facility may use various techniques for discovering and mapping lights, such as described herein or as known to those of skill in the art. Also provided is a light system composer 5004 for composing one or more lighting shows that can be displayed on a light system. The authoring of the shows may be based on geometry and an object-oriented programming approach, such as the geometry of the light systems that are 15   discovered and mapped using the mapping facility, according to various methods and systems disclosed herein or known in the art. Also provided is a light system engine, for playing lighting shows by executing code for lighting shows and delivering lighting control signals, such as to one or more lighting systems, or to related systems, such as power/data systems, that govern lighting systems. Further details of the light system 20   manager 5000, mapping facility 5002, light system composer 5004 and light system engine 5008 are provided herein.

The light system manager 5000, mapping facility 5002, light system composer 5004 and light system engine 5008 may be provided through a combination of computer 25   hardware, telecommunications hardware and computer software components. The different components may be provided on a single computer system or distributed among separate computer systems.

Referring to Fig. 28, in an embodiment, the mapping facility 5002 and the light 30   system composer 5004 are provided on an authoring computer 5010. The authoring computer 5010 may be a conventional computer, such as a personal computer. In

embodiments the authoring computer 5010 includes conventional personal computer components, such as a graphical user interface, keyboard, operating system, memory, and communications capability. In embodiments the authoring computer 5010 operates with a development environment with a graphical user interface, such as a Windows

5   environment. The authoring computer 5010 may be connected to a network, such as by any conventional communications connection, such as a wire, data connection, wireless connection, network card, bus, Ethernet connection, Firewire, 802.11 facility, Bluetooth, or other connection. In embodiments, such as in Fig. 28, the authoring computer 5010 is provided with an Ethernet connection, such as via an Ethernet switch 5102, so that it can

10 communicate with other Ethernet-based devices, optionally including the light system engine 5008, a light system itself (enabled for receiving instructions from the authoring computer 5010), or a power/data supply (PDS) 1758 that supplies power and/or data to a light system 100 comprised of one or more lighting units 102. The mapping facility 5002 and the light system composer 5004 may comprise software applications running

15 on the authoring computer 5010.

Referring still to Fig. 28, in an architecture for delivering control systems for complex shows to one or more light systems, shows that are composed using the authoring computer 5010 are delivered via an Ethernet connection through one or more

20 Ethernet switches to the light system engine 5008. The light system engine 5008 downloads the shows composed by the light system composer 5004 and plays them, generating lighting control signals for light systems. In embodiments, the lighting control signals are relayed by an Ethernet switch to one or more power/data supplies and are in turn relayed to light systems that are equipped to execute the instructions, such as

25 by turning LEDs on or off, controlling their color or color temperature, changing their hue, intensity, or saturation, or the like. In embodiments the power/data supply may be programmed to receive lighting shows directly from the light system composer 5004. In embodiments a bridge may be programmed to convert signals from the format of the light system engine 5008 to a conventional format, such as DMX or DALI signals used

30 for entertainment lighting.

Referring to Fig. 29, in embodiments the lighting shows composed using the light system composer 5004 are compiled into simple scripts that are embodied as XML documents. The XML documents can be transmitted rapidly over Ethernet connections. In embodiments, the XML documents are read by an XML parser of the light system

5   engine 5008. Using XML documents to transmit lighting shows allows the combination of lighting shows with other types of programming instructions. For example, an XML document type definition may include not only XML instructions for a lighting show to be executed through the light system engine 5008, but also XML with instructions for another computer system, such as a sound system, and entertainment system, a

10   multimedia system, a video system, an audio system, a sound-effect system, a smoke effect system, a vapor effect system, a dry-ice effect system, another lighting system, a security system, an information system, a sensor-feedback system, a sensor system, a browser, a network, a server, a wireless computer system, a building information technology system, or a communication system.

15

Thus, methods and systems provided herein include providing a light system engine for relaying control signals to a plurality of light systems, wherein the light system engine plays back shows. The light system engine 5008 may include a processor, a data facility, an operating system and a communication facility. The light system

20   engine 5008 may be configured to communicate with a DALI or DMX lighting control facility. In embodiments, the light system engine communicates with a lighting control facility that operates with a serial communication protocol. In embodiments the lighting control facility is a power/data supply for a lighting unit 102.

25   In embodiments, the light system engine 5008 executes lighting shows downloaded from the light system composer 5004. In embodiments the shows are delivered as XML files from the light system composer 5004 to the light system engine 5008. In embodiment the shows are delivered to the light system engine over a network. In embodiments the shows are delivered over an Ethernet facility. In embodiments the

30   shows are delivered over a wireless facility. In embodiments the shows are delivered over a Firewire facility. In embodiments shows are delivered over the Internet.

In embodiments lighting shows composed by the light system composer 5004 can be combined with other files from another computer system, such as one that includes an XML parser that parses an XML document output by the light system composer 5004

5   along with XML elements relevant to the other computer. In embodiments lighting shows are combined by adding additional elements to an XML file that contains a lighting show. In embodiments the other computer system comprises a browser and the user of the browser can edit the XML file using the browser to edit the lighting show generated by the lighting show composer. In embodiments the light system engine 5008

10   includes a server, wherein the server is capable of receiving data over the Internet. In embodiments the light system engine 5008 is capable of handling multiple zones of light systems, wherein each zone of light systems has a distinct mapping. In embodiments the multiple zones are synchronized using the internal clock of the light system engine 5008.

15   The methods and systems included herein include methods and systems for providing a mapping facility 5002 of the light system manager 5000 for mapping locations of a plurality of light systems. In embodiments, the mapping system discovers lighting systems in an environment, using techniques described above. In embodiments, the mapping facility then maps light systems in a two-dimensional space, such as using a

20   graphical user interface.

In embodiments of the invention, the light system engine 5008 comprises a personal computer with a Linux operating system. In embodiments the light system engine is associated with a bridge to a DMX or DALI system.

25

A light system 100 may include a network interface 4902 for delivering data from a control facility 3500 to one or more light systems 100, which may include one or more lighting units 102. The term "network" as used herein refers to any interconnection of two or more devices (including controllers or processors) that facilitates the transport of

30   information (e.g. for device control, data storage, data exchange, etc.) between any two or more devices and/or among multiple devices coupled to the network. As should be

readily appreciated, various implementations of networks suitable for interconnecting multiple devices may include any of a variety of network topologies and employ any of a variety of communication protocols. Additionally, in various networks according to the present invention, any one connection between two devices may represent a dedicated

5   connection between the two systems, or alternatively a non-dedicated connection. In addition to carrying information intended for the two devices, such a non-dedicated connection may carry information not necessarily intended for either of the two devices (e.g., an open network connection). Furthermore, it should be readily appreciated that various networks of devices as discussed herein may employ one or more wireless,

10   wire/cable, and/or fiber optic links to facilitate information transport throughout the network.

Fig. 28 illustrates one of many possible examples of a networked lighting system 100 in which a number of lighting units 102 are coupled together to form the networked

15   lighting system. Fig. 30 depicts another networked configuration for a lighting system 100.

The networked lighting system 100 may be configured flexibly to include one or more user interfaces 4908, as well as one or more signal sources 8400 such as

20   sensors/transducers 8402. For example, one or more user interfaces and/or one or more signal sources such as sensors/transducers 8402 (as discussed above in connection with Fig. 2) may be associated with any one or more of the lighting units 102 of the networked lighting system 100. Alternatively (or in addition to the foregoing), one or more user interfaces 4908 and/or one or more signal sources 8400 may be implemented

25   as "stand alone" components in the networked lighting system 100. Whether stand alone components or particularly associated with one or more lighting units 102, these devices may be "shared" by the lighting units of the networked lighting system 100. Stated differently, one or more user interfaces 4908 and/or one or more signal sources 8400 such as sensors/transducers 8402 may constitute "shared resources" in the networked

30   lighting system 100 that may be used in connection with controlling any one or more of the lighting units 102 of the system 100.

The lighting system 100 may include one or more lighting unit controllers (LUCs) 3500a, 3500b, 3500c, 3500d for lighting units 102, wherein each LUC is responsible for communicating with and generally controlling one or more lighting units

5   102 coupled to it. Different numbers of lighting units 102 may be coupled to a given LUC in a variety of different configurations using a variety of different communication media and protocols.

Each LUC in turn may be coupled to a central control facility 3500 that is

10   configured to communicate with one or more LUCs. Although Fig. 2 shows four LUCs coupled to the central controller 3500 via a switching or coupling device 3004, it should be appreciated that according to various embodiments, different numbers of LUCs may be coupled to the central controller 3500. Additionally, according to various embodiments of the present invention, the LUCs and the central controller 3500 may be

15   coupled together in a variety of configurations using a variety of different communication media and protocols to form the networked lighting system 100. Moreover, it should be appreciated that the interconnection of LUCs 3500a, 3500b, 3500c, 3500d and the central controller 3500, and the interconnection of lighting units 102 to respective LUCs, may be accomplished in different manners (e.g., using different

20   configurations, communication media, and protocols).

For example, according to one embodiment of the present invention, the central controller 3500 shown in Fig. 30 may be configured to implement Ethernet-based communications with the LUCs, and in turn the LUCs may be configured to implement

25   DMX-based communications with the lighting units 102. In particular, in one aspect of this embodiment, each LUC may be configured as an addressable Ethernet-based controller and accordingly may be identifiable to the central controller 3500 via a particular unique address (or a unique group of addresses) using an Ethernet-based protocol. In this manner, the central controller 3500 may be configured to support

30   Ethernet communications throughout the network of coupled LUCs, and each LUC may respond to those communications intended for it. In turn, each LUC may communicate

lighting control information to one or more lighting units coupled to it, for example, via a DMX protocol, based on the Ethernet communications with the central controller 3500.

More specifically, according to one embodiment, the LUCs 3500a, 3500b, 3500c and 3500d shown in Fig. 30 may be configured to be "intelligent" in that the central controller 3500 may be configured to communicate higher level commands to the LUCs that need to be interpreted by the LUCs before lighting control information can be forwarded to the lighting units 102. For example, a lighting system operator may want to generate a color changing effect that varies colors from lighting unit to lighting unit in such a way as to generate the appearance of a propagating rainbow of colors ("rainbow chase"), given a particular placement of lighting units with respect to one another. In this example, the operator may provide a simple instruction to the central controller 3500 to accomplish this, and in turn the central controller may communicate to one or more LUCs using an Ethernet-based protocol high-level command to generate a "rainbow chase." The command may contain timing, intensity, hue, saturation or other relevant information, for example. When a given LUC receives such a command, it may then interpret the command so as to generate the appropriate lighting control signals which it then communicates using a DMX protocol via any of a variety of signaling techniques (e.g., PWM) to one or more lighting units that it controls.

It should again be appreciated that the foregoing example of using multiple different communication implementations (e.g., Ethernet/DMX) in a lighting system according to one embodiment of the present invention is for purposes of illustration only, and that the invention is not limited to this particular example.

In embodiments the central controller 3500 may be a network controller that controls other functions, such as a home network, business enterprise network, building network, or other network.

In embodiments a switch, such as a wall switch, can include a processor 3600, memory 3700 and a communications port for receiving data. The switch can be linked to

a network, such as an office network, Internet, or home network. Each switch can be an intelligent device that responds to communication signals via the communications port to provide control of any lighting units 102 from any location where another switch or intelligent device may be located. Such a switch can be integrated through smart

5 interfaces and networks to trigger shows (such as using a lighting control player, such as iPlayer 2 available from Color Kinetics) as with a lighting controller such as a ColorDial from Color Kinetics. Thus, the switch can be programmed with light shows to create various aesthetic, utilitarian or entertainment effects, of white or non-white colors. In embodiments, an operator of a system can process, create or download shows, including

10 from an external source such as the Internet. Shows can be sent to the switch over a communication facility of any kind. Various switches can be programmed to play back and control any given lighting unit 102. In embodiments, settings can be controlled through a network or other interface, such as a web interface.

15 A switch with a processor 3600 and memory 3700 can be used to enable upgradeable lighting units 102. Thus, lighting units 102 with different capabilities, shows, or features can be supplied, allowing users to upgrade to different capabilities, as with different versions of commercial software programs. Upgrade possibilities include firmware to add features, fix bugs, improve performance, change protocols, add

20 capability and provide compatibility, among others.

In embodiments a control facility 3500 may be based on stored modes and a power cycle event. The operator can store modes for lighting control, such as on a memory 3700. The system can then look for a power event, such as turning the power

25 on or off. When there is a power event the system changes mode. The mode can be a resting mode, with no signal to the lighting unit 102, or it can be any of a variety of different modes, such as a steady color change, a flashing mode, a fixed color mode, or modes of different intensity. Modes can include white and non-white illumination modes. The modes can be configured in a cycle, so that upon a mode change, the next

30 stored mode is retrieved from memory 3700 and signals for that mode are delivered to the lighting unit 102, such as using a switch, slide, dial, or dimmer. The system can take

an input signal, such as from the switch. Depending on the current mode, the input signal from the switch can be used to generate a different control signal. For example, if the mode is a steady color change, the input from the dimmer could accelerate of decelerate the rate of change. If the mode were a single color, then the dimmer signal

5   could change the mode by increasing or decreasing the intensity of light. Of course, system could take multiple inputs from multiple switches, dials, dimmers, sliders or the like, to provide more modulation of the different modes. Finally, the modulated signal can be sent to the lighting unit 102.

10   In embodiments a system with stored modes can take input, such as from a signal source 8400, such as a sensor, a computer, or other signal source. The system can determine the mode, such as based on a cycle of modes, or by recalling modes from memory, including based on the nature of the signal from the signal source 8400. Then system can generate a control signal for a lighting unit, based on the mode.

15

                Referring to Fig. 31a, the methods and systems disclosed herein may further comprise disposing a plurality of lighting units 102 in a serial configuration and controlling all of them by a stream of data to respective processors 3600, such as ASICS, of each of them, wherein each lighting unit 102 responds to the first unmodified bit of

20   data in the stream, modifies that bit of data, and transmits the stream to the next ASIC. Using such a serial addressing protocol, data can be addressed to lighting units 102 based on their location in a series of lighting units 102, rather than requiring knowledge of the exact physical location of each lighting unit 102.

25   Methods and system provided herein also include providing a self-healing lighting system, which may include providing a plurality of lighting units in a system, each having a plurality of light sources; providing at least one processor associated with at least some of the lighting units for controlling the lighting units; providing a network facility for addressing data to each of the lighting units; providing a diagnostic facility

30   for identifying a problem with a lighting unit; and providing a healing facility for

modifying the actions of at least one processor to automatically correct the problem

identified by the diagnostic facility.

A lighting unit controller according to the present invention may include a unique

5   address such that the 208 can be identified and communicated with. The LUC may also

include a universe address such that the lighting unit controller can be grouped with

other controllers or systems and addressed information can be communicated to the

group of systems. The lighting unit controller may also have a broadcast address, or

otherwise listen to general commands provided to many or all associated systems.

10

Referring to Fig. 31b, the network interface 4900 may include a network

topology with a control facility 3500 and multiple lighting units 102 disposed on the

network in a hub-router configuration. Referring to Fig. 31c, the lighting units 102 can

be disposed along a high-speed serial bus for receiving control signals from a data

15   facility 3500.

A lighting unit 102 may include a physical data interface 4904 for receiving data,

such as from another lighting unit 102, from a signal source 8400, from a user interface

4902, or from a control facility 3500. Referring to Fig. 32, the lighting unit 102 may

include one or more communication ports 4904 to facilitate coupling of the lighting unit

102 to any of a variety of other devices. For example, one or more communication ports

4904 may facilitate coupling multiple lighting units together as a networked lighting

system, in which at least some of the lighting units are addressable (e.g., have particular

identifiers or addresses) and are responsive to particular data transported across the

network.

In embodiments the communication port 4904 can receive a data cable, such as a

standard CAT 5 cable type used for networking. Thus, the lighting unit 102 can receive

20   data, such as from a network. By allowing connection of the lighting unit 102 to a

communications port 4904, the system allows a lighting designer or installer to send data

to a plurality of lighting units 102 to put them in common modes of control and illumination, providing more consistency to the lighting of the overall environment.

Fig. 33 shows various embodiments of physical data interfaces 4902. Fig. 33a shows an embodiment arranged in a wireless network arrangement, using a wireless data interface as the physical data interface, such as a radio frequency interface, infrared interface, Bluetooth interface, 802.11 interface, or other wireless interface. In embodiments the wireless arrangement is a peer-to-peer arrangement. In embodiments such as Fig. 33b, the arrangement is a master-slave arrangement, where on lighting unit 102 controls other lighting units 102 in close proximity. Fig. 33c a retrofit lighting unit 102 with a communication port 4904. Fig. 33e shows a socket 3302 or fixture for receiving a lighting unit 102. In this case the socket 3302 includes a processor 3600, such as to providing control signals to the lighting unit 102. The socket 3600 can be connected to a control interface 4900, such as a network, so that it can receive signals, such as from a control facility 3500. Thus, the socket 3302 can serve as a lighting unit controller. By placing control in the socket 3302, it is possible for a lighting designer or installer to provide control signals to a known location, regardless of what bulbs are removed or replaced into the socket 3302. Thus, an environmental lighting system can be arranged by the sockets 3302, then any different lighting units 102 can be installed, responsive to control signals sent to the respective sockets 3302. Sockets 3302 can be configured to receive any kind of light bulb, including incandescent, fluorescent, halogen, metal halide, LED-based lights, or the like. Thus, intelligence can be provided by the processor 3600 to a conventional socket. In embodiments, data can be provided over power lines, thus avoiding the need to rewire the environment, using power line carrier techniques as known in the art, the X10 system being one such example, and the HomeTouch system being another.

In the preceding embodiments, a fixture or network can give a lighting unit 102 a command to set to a particular look including, color, color temperature, intensity, saturation, and spectral properties. Thus, when the designer sets the original design he or she may specify a set of particular light bulb parameters so that when a lighting unit 102

is replaced the fixture or network can perform a startup routine that initializes that lighting unit 102 to a particular set of values which are then controlled. In embodiments, the lighting unit 102 identifies itself to the network when the power is turned on. The lighting unit 102 or fixture or socket 3302 can be assigned an address by the central

5   control facility 3500, via a network interface 4900. Thus, there is an address associated with the fixture or socket 3302, and the lighting unit 102 control corresponds to that address. The lighting unit 102 parameters can be set in memory 3700, residing in either the lighting unit 102, socket 3302 or fixture, cable termination 3304 or in a central control facility 3500. The lighting unit 102 can now be set to those parameters. From

10   then on, when the lighting unit 102 is powered up it receives a simple command value already set within the set of parameters chosen by the designer.

       As used herein, the terms "wired" transmission and or communication should be understood to encompass wire, cable, optical, or any other type of communication where

15   the devices are physically connected. As used herein, the terms "wireless" transmission and or communication should be understood to encompass acoustical, RF, microwave, IR, and all other communication and or transmission systems were the devices are not physically connected.

20   Referring to Fig. 33e, the physical data interface 4904 can include a processor included in an end of a cable 3304, so that the cable itself is a lighting unit controller, such as to ensure that as lighting units 102 are replaced, any lighting unit attached to that cable 3304 will respond to signals intended to be addressed to locations of that cable. 3304. This is helpful in environments like airline cabins, where maintenance staff may

25   not have time to enter address information for replacement lighting units 102 when earlier units fail.

       A lighting unit 102 can respond to input from a user interface 4908. The term "user interface" as used herein refers to an interface between a human user or operator

30   and one or more devices that enable communication between the user and the device(s). Examples of user interfaces that may be employed in various implementations of the

present invention include, but are not limited to, switches, human-machine interfaces, operator interfaces, potentiometers, buttons, dials, sliders, a mouse, keyboard, keypad, various types of game controllers (e.g., joysticks), track balls, display screens, various types of graphical user interfaces (GUIs), touch screens, microphones and other types of

5   sensors that may receive some form of human-generated stimulus and generate a signal in response thereto.

In another aspect, as also shown in Fig. 2, the lighting unit 102 optionally may include one or more user interfaces 4908 that are provided to facilitate any of a number of user-selectable settings or functions (e.g., generally controlling the light output of the lighting unit 102, changing and/or selecting various pre-programmed lighting effects to be generated by the lighting unit, changing and/or selecting various parameters of selected lighting effects, setting particular identifiers such as addresses or serial numbers for the lighting unit, etc.). In various embodiments, the communication between the user interface 4908 and the lighting unit may be accomplished through wire or cable, or wireless transmission.

In one implementation, the processor 3600 of the lighting unit monitors the user interface 4908 and controls one or more of the light sources 300 based at least in part on

10   a user's operation of the interface. For example, the processor 3600 may be configured to respond to operation of the user interface by originating one or more control signals for controlling one or more of the light sources. Alternatively, the processor 3600 may be configured to respond by selecting one or more pre-programmed control signals stored in memory, modifying control signals generated by executing a lighting program,

15   selecting and executing a new lighting program from memory, or otherwise affecting the radiation generated by one or more of the light sources.

In particular, in one implementation, the user interface 4908 may constitute one or more switches (e.g., a standard wall switch) that interrupt power to the processor

20   3600. In one aspect of this implementation, the processor 3600 is configured to monitor the power as controlled by the user interface, and in turn control one or more of the light

sources 300 based at least in part on a duration of a power interruption caused by operation of the user interface. As discussed above, the processor may be particularly configured to respond to a predetermined duration of a power interruption by, for example, selecting one or more pre-programmed control signals stored in memory,

5   modifying control signals generated by executing a lighting program, selecting and executing a new lighting program from memory, or otherwise affecting the radiation generated by one or more of the light sources.

Referring to Fig. 34 simple user interfaces can be used to trigger control signals.

10   Fig. 34a shows a push button 3402 that triggers stored modes when pressed. Fig. 34b and Fig. 34c show user interfaces 4908 involving slides 3404 that can change the intensity or color, depending on the mode. A dual slide is shown in Fig. 34c, where one slide 3404 can adjust color and the other can adjust intensity, or the like. Fig. 34d and Fig. 34e show dials 3408. The dial can trigger stored modes or adjust color or intensity

15   of light. The dual-dial embodiment of Fig. 34e can include one dial for color and another for intensity. Fig. 34f shows a dial 3408 that includes a processor 3600 and memory 3700, so that the user interface can provide basic instructions, such as for stored modes, but the user interface 4908 also reacts to instructions from a central control facility 3500. Fig. 34g shows a dipswitch 3410, which can beg used to set simple modes

20   of a lighting unit 102. Fig. 34h shows a microphone 3412, such as for a voice recognition facility interface to a lighting unit 102, such as to trigger lighting by voice interaction. In embodiments such as fig. 34a, the slide can provide voltage input to a lighting unit 102, and the switch can allow the user to switch between modes of operation, such as by selecting a color wash, a specific color or color temperature, a

25   flashing series of colors, or the like.

In various embodiments the slides, switches, dials, dipswitches and the like can be used to control a wide range of variables, such as color, color temperature, intensity, hue, and triggering of lighting shows of varying attributes.

30

In other embodiments of the present invention it may be desirable to limit user control. Lighting designers, interior decorators and architects often prefer to create a certain look to their environment and wish to have it remain that way over time. Unfortunately, over time, the maintenance of an environment, which includes light bulb

5   replacement, often means that a lighting unit, such as a bulb, is selected whose properties differ from the original design. This may include differing wattages, color temperatures, spectral properties, or other characteristics. It is desirable to have facilities for improving the designer's control over future lighting of an environment.

10   Referring to Fig. 34i, in embodiments a dial allows a user to select one or more colors or color temperatures from a scale 3414. For example, the scale 3414 can include different color temperatures of white light. The lighting designer can specify use of a particular color temperature of light, which the installer can select by setting the right position on the scale 3414 with the dial. A slide mechanism can be used like the dial to

15   set a particular color temperature of white light, or to select a particular color of non-white light, in either case on a scale. Again, the designer can specify a particular setting, and the installer can set it according to the design plan. Providing adjustable lighting units 102 offers designers and installers much greater control over the correct maintenance of the lighting of the environment.

20

In embodiments, the fixture, socket 3302 or lighting unit 102 can command color setting at installation, either a new setting or a fine adjustment to provide precise color control. In embodiments, the lighting unit 102 allows color temperature control as described elsewhere. The lighting unit 102 is settable, but the fixture itself stores an

25   instruction or value for the setting of a particular color temperature or color. Since the fixture is set, the designer or architect can insure that all settable lighting units 102 will be set correctly when they are installed or replaced. An addressable fixture can be accomplished through a cable connection where the distal end of the cable, at the fixture, has a value programmed or set. The value is set through storage in memory 3700 or over

30   the power lines. A physical connection can be made with a small handheld device, such as a Zapi available from Color Kinetics, to create and set the set of parameters for that

fixture and others. If the environment changes over time, as for example during a remodeling, then those values can be updated and changed to reflect a new look for the environment. A person could either go from fixture to fixture to reset those values or change those parameters remotely to set an entire installation quickly. Once the area is

5   remodeled or repainted, as in the lobby of a hotel for example, the color temperature or color can be reset and, for example, have all lighting units 102 in the lobby set to white light of 3500K. Then, in the future, is any lighting unit 102 is replaced or upgraded, any bulb plugged in can be set to that new value. Changes to the installation parameters can be done in various ways, such as by network commands, or wireless communication,

10   such as RF or IR communication.

In various embodiments, the setting can occur in the fixture or socket 3302, in the distal end of a cable 3304, in the proximal end of the cable 3304, or in a central control facility 3500. The setting can be a piece of memory 3700 embedded in any of those

15   elements with a facility for reading out the data upon startup of the lighting unit 102.

In other embodiments it may be desirable to prevent or deter user adjustment. A lighting unit 102 can be programmed to allow adjustment and changes to parameters by a lighting designer or installer, but not by other users. Such systems can incorporate a

20   lockout facility to prevent others from easily changing the settings. This can take the form of memory 3700 to store the current state but allow only a password-enabled user to make changes. One embodiment is a lighting unit 102 that is connected to a network or to a device that allows access to the lighting unit 102 or network. The device can be an authorized device whose initial communication establishes trust between two devices or

25   between the device and network. This device can, once having established the connection, allow for the selection or modification of pattern, color, effect or relationship between other devices such as ambient sensors or external devices. The system can store modes, such as in memory 3700. The system can detect a user event, such as an attempt by the user to change modes, such as sending an instruction over a network or wireless

30   device. The system queries whether the user is authorized to change the mode of the lighting unit 102, such as by asking for a password, searching for a stored password, or

checking a device identifier for the device through which the user is seeking to change the mode of the lighting unit 102. If the user is not authorized, then the system maintains the previous mode and optionally notifies the lighting designer, installer, or other individual of the unauthorized attempt to change the mode. If the user is authorized,

5   then the user is allowed to change the mode. Facilities for allowing only authorized users to trigger events are widely known in the arts of computer programming, and any such facilities can be used with a processor 3600 and memory 3700 used with a lighting unit 102.

10   In other embodiments, the lighting designer can specify changes in color over time or based on time of day or season of year. It is beneficial for a lighting unit 102 to measure the amount of time that it has been on and store information in a compact form as to its lighting history. This provides a useful history of the use of the light and can be correlated to use lifetime and power draw, among other measurements. An intelligent

15   networked lighting unit 102 can store a wide variety of useful information about its own state over time and the environmental state of its surroundings. A lighting unit can store a histogram, a chart representing value and time of lighting over time. The histogram can be stored in memory 3700. A histogram can chart on time versus off time for a lighting unit 102. A histogram can be correlated to other data, such as room habitation, to

20   develop models of patterns of use, which can then be tied into a central control facility 3500, such as integrated with a building control system.

       In embodiments a user interface 4908 instructs a lighting system 100 to produce a desired mixed light output. The user interface can be a remote control, a network

25   interface, a dipswitch, a computer, such as a laptop computer, a personal computer, a network computer, or a personal digital assistant, an interface for programming an on-board memory of the illumination system, a wireless interface, a digital facility, a remote control, a receiver, a transceiver, a network interface, a personal computer, a handheld computer, a push button, a dial, a toggle/membrane switch, an actuator that actuates

30   when one part of a housing is rotated relative to another, a motion sensor, an insulating strip that is removed to allow power to a unit, an electrical charge to turn a unit on, or a

magnetic interface such as a small reed-relay or Hall-effect sensor that can be incorporated so when a magnetic material is brought within the proximity of the device it completes a power circuit.

5   Referring to Fig. 35a, a user interface 4908 may include a browser 3550 running on a computer. The browser 3550 may be used to trigger shows, such as ones stored locally at a power data supply 1758 connected to a network, such as through an Ethernet switch. In general a computer may supply a graphical user interface for authoring and triggering shows, as described in more detail below. Fig. 35b shows a graphical user

10   interface 3502 for a playback controller that can control the playback of shows, such as ones stored in memory 3700 of a lighting system 100.

           In embodiments a keypad 3650 may be used to store control signals for lighting shows. Buttons 3652 on the keypad 3650 may be used to trigger stored shows, such as to

15   be delivered directly to lighting units 102 or to deliver them across a network, such as in the Ethernet configuration of Fig. 36.

           In embodiments it may be important to provide an addressing facility 6600 for providing an address to a lighting unit 102 or light system 100. An address permits a

20   particular lighting unit 102 to be identified among a group of lighting units 102 or a group of lighting units 102 to be identified among a larger group, or a group of other devices deployed on a common network. An address in turn permits use of the mapping facility 5002 for mapping locations of lighting units 102 according to their unique identifiers or addresses. Once locations are mapped, it is possible to deliver control

25   signals to the lighting units 102 in desired sequences to create complex effects, such as color-chasing rainbows, or the like, based on their correct locations in the world.

           The term "addressable" is used herein to include a device (e.g., a light source in general, a lighting unit or fixture, a controller or processor associated with one or more

30   light sources or lighting units, other non-lighting related devices, etc.) that is configured to receive information (e.g., data) intended for multiple devices, including itself, and to

selectively respond to particular information intended for it. The term "addressable"
often is used in connection with a networked environment (or a "network," discussed
further below), in which multiple devices are coupled together via some communications
medium or media.

5

In one implementation, one or more devices coupled to a network may serve as a
controller for one or more other devices coupled to the network (e.g., in a master / slave
relationship). In another implementation, a networked environment may include one or
more dedicated controllers that are configured to control one or more of the devices
10   coupled to the network. Generally, multiple devices coupled to the network each may
have access to data that is present on the communications medium or media; however, a
given device may be "addressable" in that it is configured to selectively exchange data
with (i.e., receive data from and/or transmit data to) the network, based, for example, on
one or more particular identifiers (e.g., "addresses") assigned to it.

15

More specifically, one embodiment of the present invention is directed to a
system of multiple controllable lighting units coupled together in any of a variety of
configurations to form a networked lighting system. In one aspect of this embodiment,
each lighting unit has one or more unique identifiers (e.g., a serial number, a network
20   address, etc.) that may be pre-programmed at the time of manufacture and/or installation
of the lighting unit, wherein the identifiers facilitate the communication of information
between respective lighting units and one or more lighting system controllers. In another
aspect of this embodiment, each lighting unit 102 may be flexibly deployed in a variety
of physical configurations with respect to other lighting units of the system, depending
25   on the needs of a given installation.

One issue that may arise in such a system of multiple controllable lighting units
102 is that upon deployment of the lighting units 102 for a given installation, it is in
some cases challenging to configure one or more system controllers *a priori* with some
30   type of mapping information that provides a relationship between the identifier for each
lighting unit 102 and its physical location relative to other lighting units 102 in the

system. In particular, a lighting system designer/installer may desire to purchase a number of individual lighting units each pre-programmed with a unique identifier (e.g., serial number), and then flexibly deploy and interconnect the lighting units in any of a variety of configurations to implement a networked lighting system. At some point

5   before operation, however, the system needs to know the identifiers of the controllable lighting units deployed, and preferably their physical location relative to other units in the system, so that each unit may be appropriately controlled to realize system-wide lighting effects.

10   Referring to Fig. 37, one way to accomplish mapping is to have one or more system operators and/or programmers manually create one or more custom system configuration files 3700 containing the individual identifiers 3702 for each lighting unit 102 and corresponding mapping information that provides some means of identifying the relative physical locations 3708 of lighting units 102 in the system. Configuration files

15   3700 can include other attributes, such as the positions lit by a lighting unit 102, as well as the positions of the lighting units 102 themselves. As the number of lighting units 192 deployed in a given system increases and the physical geometry of the system becomes more complex, however, and the process of creating manual configuration files can quickly become unwieldy. Rather than manually entering configuration data, it is

20   desirable to have other methods of detecting addresses and mapping addresses of lighting units 102 to physical locations.

In view of the foregoing, one embodiment of the invention is directed to methods and systems that facilitate a determination of the respective identifiers of controllable

25   lighting units coupled together to form a networked lighting system. In one aspect of this embodiment, each lighting unit of the system has a pre-programmed multiple-bit binary identifier, and a determination algorithm is implemented to iteratively determine (i.e., "learn") the identifiers of all lighting units that make up the system. In various aspects, such determination/learning algorithms may employ a variety of detection

30   schemes during the identifier determination process, including, but not limited to, monitoring a power drawn by lighting units at particular points of the process, and/or

monitoring an illumination state of one or more lighting units at particular points of the determination process.

Once the collection of identifiers for all lighting units of the system is determined (or manually entered), another embodiment of the present invention is directed to facilitating the compilation of mapping information that relates the identified lighting units 102 to their relative physical locations in the installation. In various aspects of this embodiment, the mapping information compilation process may be facilitated by one or more graphical user interfaces that enable a system operator and/or programmer to conveniently configure the system based on either learned and/or manually entered identifiers of the lighting units, as well as one or more graphic representations of the physical layout of the lighting units relative to one another.

In an embodiment, identifiers for lighting units 102 can be determined by a series of steps. First, a set of lighting units 102 having unique identifiers stored in memory 3700 are provided. Next, address identification information is provided to the lighting units. Next, the lighting unit 102 is caused to read the address identification information, compare the address identification information to at least a portion of the identifier, and cause the lighting unit 102 to respond to the address identification information by either energizing or de-energizing one or more light sources of the lighting unit 102. Finally, the system monitors the power consumed by the lighting unit to provide an indication of the comparison between the identifier and the address identification information..

In embodiments each lighting unit controller includes a power sensing module that provides one or more indications to the LUC when power is being drawn by one or more lighting units coupled to the LUC (i.e., when one or more light sources of one or more of the lighting units is energized). The power-sensing module also may provide one or more output signals to the processor 3600, and the processor 3600 in turn may communicate to the central control facility 3500 information relating to power sensing.

The power sensing module, together with the processor 3600, may be adapted to determine merely when any power is being consumed by any of the lighting units coupled to the LUC, without necessarily determining the actual power being drawn or the actual number of units drawing power. As discussed further below, such a "binary"

5   determination of power either being consumed or not consumed by the collection of lighting units 102 coupled to the LUC facilitates an identifier determination/learning algorithm (e.g., that may be performed by the LUC processor 3600 or the central control facility 3500) according to one embodiment of the invention. In other aspects, the power sensing module and the processor 3600 may be adapted to determine, at least

10   approximately, and actual power drawn by the lighting units at any given time. If the average power consumed by a single lighting unit is known *a priori*, the number of units consuming power at any given time can then be derived from such an actual power measurement. Such a determination is useful in other embodiments of the invention, as discussed further below.

15

As discussed above, according to one embodiment of the invention, the LUC processor 3600 may monitor the output signal from the power sensing module to determine if any power is being drawn by the group of lighting units, and use this indication in an identifier determination/learning algorithm to determine the collection of

20   identifiers of the group of lighting units coupled to the LUC. For purposes of illustrating the various concepts related to such an algorithm, the following discussion assumes an example of a unique four bit binary identifier for each of the lighting units coupled to a given LUC. It should be appreciated, however, that lighting unit identifiers according to the present invention are not limited to four bits, and that the following example is

25   provided primarily for purposes of illustration.

Fig. 38 illustrates a binary search tree 3800 based on four bit identifiers for lighting units, according to one embodiment of the invention. In Fig. 38, it is assumed that three lighting unit 102 are coupled to a generic LUC, and that the first lighting unit

30   has a first binary identifier 3802A of one, one, zero, one (1101), the second lighting unit has a second binary identifier 3802B of one, one, zero, zero (1100), and the third lighting

unit has a third binary identifier 3802C of one, zero, one, one (1011). Referring to Fig. 39, exemplary identifiers are used below to illustrate an example of an identifier determination / learning algorithm depicted in Fig. 39.

5   In embodiments, the collection of identifiers corresponding to the respective units and the number of units are determined. However, it should be appreciated that no particular determination is made of which lighting unit has which identifier. Stated differently, the algorithm does not determine a one-to-one correspondence between identifiers and lighting units, but rather merely determines the collection of identifiers of

10   all of the lighting units coupled to the LUC. According to one embodiment of the invention, such a determination is sufficient for purposes of subsequently compiling mapping information regarding the physical locations of the lighting units relative to one another.

15   One or both of a given LUC processor 3600 or the central control facility 3500 may be configured to execute the algorithm, and that either the processor 3600 or the central control facility 3500 may include memory 3700 to store a flag for each bit of the identifier, which flag may be set and reset at various points during the execution of the algorithm, as discussed further below. Furthermore, for purposes of explaining the

20   algorithm, it is to be understood that the "first bit" of an identifier refers to the highest order binary bit of the identifier. In particular, with reference to the example of Fig. 38, the four identifier bits are consecutively indicated as a first bit 3804, a second bit 3808, a third bit 3810, and a fourth bit 3812.

25   Referring again to the exemplary identifiers and binary tree illustrated in Fig. 38, the mapping algorithm implements a complete search of the binary tree to determine the identifiers of all lighting units coupled to a given LUC. The algorithm begins by selecting a first state (either a 1 or a 0) for the highest order bit 3804 of the identifier, and then sends a global command to all of the lighting units coupled to the LUC to energize

30   one or more of their light sources if their respective identifiers have a highest order bit corresponding to the selected state. Again for purposes of illustration, it is assumed here

that the algorithm initially selects the state "1" (indicated with the reference character 3814 in Fig. 38). In response to this command, all of the lighting units energize their light sources and, hence, power is drawn from the LUC. It should be appreciated, however, that the algorithm may initially select the state "0" (indicated with the reference

5   character 3818 in Fig. 38); in the present case, since no lighting unit has an identifier with a "0" in the highest order bit 3804, no power would be drawn from the LUC and the algorithm would respond by setting a flag for this bit, changing the state of this bit, and by default assume that all of the lighting units coupled to the LUC necessarily have a "1" in the highest order bit (as is indeed the case for this example).

10

As a result of a "1" in the highest order bit having been identified, the algorithm adds another bit 3808 with the same state (i.e., "1"), and then sends a global command to all of the lighting units to energize their light sources if their respective identifiers begin with "11" (i.e., 11XX). As a result of this query, the first and second lighting units

15   energize their light sources and draw power, but the third lighting unit does not energize. In any event, some power is drawn, so the algorithm then queries if there are any more bits in the identifier. In the present example there are more bits, so the algorithm returns to adding another bit 3810 with the same state as the previous bit and then sends a global command to all lighting units to energize their light sources if their respective identifiers

20   begin with "111" (i.e., 111X).

At this point in the example, no identifiers correspond to this query, and hence no power is drawn from the LUC. Accordingly, the algorithm sets a flag for this third bit 3810, changes the state of the bit (now to a "0"), and again queries if there are any more

25   bits in the identifier. In the present example there are more bits, so the algorithm returns to adding another bit 3812 with the same state as the previous bit (i.e., another "0") and then sends a global command to all lighting units to energize their light sources if they have the identifier "1100."

30   In response to this query, the second lighting unit energizes its light sources and hence power is drawn from the LUC. Since there are no more bits in the identifiers, the

algorithm has thus learned a first of the three identifiers, namely, the second identifier 3802B of "1100." At this point, the algorithm checks to see if a flag for the fourth bit 3812 has been set. Since no flag yet has been set for this bit, the algorithm changes the bit state (now to a "1"), and sends a global command to all lighting units to energize their

5   light sources if they have the identifier "1101." In the present example, the first lighting unit energizes its light sources and draws power, indicating that yet another identifier has been learned by the algorithm, namely, the first identifier 3802A of "1101."

At this point, the algorithm goes back one bit in the identifier (in the present

10   example, this is the third bit 3810) and checks to see if a flag was set for this bit. As pointed out above, indeed the flag for the third bit was set (i.e., no identifiers corresponded to "111X"). The algorithm then checks to see if it has arrived back at the first (highest order) bit 3804 again, and if not, goes back yet another bit (to the second bit 3808). Since no flag has yet been set for this bit (it is currently a "1"), the algorithm

15   changes the state of the second bit (i.e., to a "0" in the present example), and sends a global command to all lighting units to energize their light sources if their respective identifiers begin with "10" (i.e., 10XX). In the current example, the third lighting unit energizes its light sources, and hence power is drawn. Accordingly, the algorithm then sets the flag for this second bit, clears any lower order flags that may have been

20   previously set (e.g., for the third or fourth bits 3810 and 3812), and returns to adding another bit 3810 with the same state as the previous bit. From this point, the algorithm executes as described above until ultimately it learns the identifier 1402C of the third lighting unit (i.e., 1011), and determines that no other lighting units are coupled to the LUC.

25

Again, it should be appreciated that although an example of four bit identifiers was used for purposes of illustration, the algorithm may be applied similarly to determine identifiers having an arbitrary number of bits. Furthermore, it should be appreciated that this is merely one example of an identifier determination / learning

30   algorithm, and that other methods for determining/learning identifiers may be implemented according to other embodiments of the invention.

Referring to Fig. 40, in another embodiment, the lighting unit controller may not include a power monitoring system but the methodology of identifying lighting unit addresses according to the principles of the present invention may still be achieved. For
5   example, rather than monitoring the power consumed by one or more lighting units, a visible interpretation of the individual lighting units may be recorded, either by human intervention or another image capture system such as a camera or video recorder. In this case, the images of the light emitted by the individual lighting units may be recorded for each bit identification and it may not be necessary to go up and down the binary task tree
10   as identified above.

The method may involve the controlling of light from a plurality of lighting units that are capable of being supplied with addresses (identifiers). The method may comprise the steps of equipping each of the lighting units with a processing facility for
15   reading data and providing instructions to the lighting units to control at least one of the color and the intensity of the lighting units, each processing facility capable of being supplied with an address. For example, the lighting units may include a lighting unit 102 where the processor 3600 is capable of receiving network data. The processor may receive network data and operate the LED(s) 300 in a manner consistent with the
20   received data. The processor may read data that is explicitly or implicitly addressed to it or it may respond to all of the data supplied to it. The network commands may be specifically targeting a particular lighting unit with an address or group of lighting units with similar addresses or the network data may be communicated to all network devices. A communication to all network devices may not be addressed but may be a universe or
25   world style command.

The method may further comprise the step of supplying each processor with an identifier, the identifier being formed of a plurality of bits of data. For example, each lighting unit 102 may be associated with memory 3700 (e.g. EPROM) and the memory
30   3700 may contain a serial number that is unique to the light or processor. Of course, the setting of the serial number or other identifier may be set through mechanical switches or

other devices and the present invention is not limited by a particular method of setting

the identifier. The serial number may be a 32-bit number in EPROM for example.

The method may also comprise sending to a plurality of such processors an

5   instruction, the instruction being associated with a selected and numbered bit of the

plurality of bits of the identifier, the instruction causing the processor to select between

an "on" state of illumination and an "off" state of illumination for light sources

controlled by that processor, the selection being determined by the comparison between

the instruction and the bit of the identifier corresponding to the number of the numbered

10   bit of the instruction. For example, a network command may be sent to one or more

lighting units in the network of lighting units. The command may be a global command

such that all lighting units that receive the command respond. The network command

may instruct the processors 102 to read the first bit of data associated with its serial

number. The processor 3600 may then compare the first bit to the instructions in the

15   network instruction or assess if the bit is a one or a zero. If the bit is a one, the processor

may turn the lighting unit on or to a particular color or intensity. This provides a visual

representation of the first bit of the serial number. A person or apparatus viewing the

light would understand that the first bit in the serial number is either a one (e.g. light is

on) or a zero (e.g. light is off). The next instruction sent to the light may be to read and

20   indicate the setting of the second bit of the address. This process can be followed for

each bit of the address allowing a person or apparatus to decipher the address by

watching the light sources of the lighting unit turn on and/or off following each

command.

25   After reducing ambient light at a step 4002, a camera may capture at a step 4006

a representation of which lights are turned on at a step 4004. The method may further

comprise capturing a representation of which lighting units are illuminated and which

lighting units are not illuminated for that instruction. For example, a camera, video or

other image capture system may be used to capture the image of the lighting unit(s)

30   following each such network command. Repeating the preceding two steps for all

numbered bits of the identifier allows for the reconstruction of the serial number of each

lighting unit in the network at an analysis step 4008. At a step 4012 the analysis is used to generate a table of mapping data for lighting units 102.

The method may further comprise assembling the identifier for each of the lighting units, based on the "on" or "off" state of each bit of the identifier as captured in the representation. For example, a person could view the lighting unit's states and record them to decipher the lighting unit's serial number or software can be written to allow the automatic reading of the images and the reassembly of the serial numbers from the images. The software may be used to compare the state of the lighting unit with the instruction to calculate the bit state of the address and then proceed to the next image to calculate the next bit state. The software may be adapted to calculate a plurality or all of the bit states of the associated lighting units in the image and then proceed to the next image to calculate the next bit state. This process could be used to calculate all of the serial numbers of the lighting units in the image.

The method may also comprise assembling a correspondence between the known identifiers (e.g. serial numbers) and the physical locations of the lighting units having the identifiers. For example, the captured image not only contains lighting unit state information but it also contains lighting unit position information. The positioning may be relative or absolute. For example, the lighting units may be mounted on the outside of a building and the image may show a particular lighting unit is below the third window from the right on the seventy second floor. This lighting unit's position may also be referenced to other lighting unit positions such that a map can be constructed which identifies all of the identifiers (e.g. serial numbers) with a lighting unit and its position. Once these positions and/or lighting units are identified, network commands can be directed to the particular lighting units by addressing the commands with the identifier and having the lighting unit respond to data that is addressed to its identifier. The method may further comprise controlling the illumination from the lighting units by sending instructions to the desired lighting units at desired physical locations. Another embodiment may involve sending the now identified lighting units address information such that the lighting units store the address information as its address and will respond

to data sent to the address. This method may be useful when it is desired to address the lighting units in some sequential scheme in relation to the physical layout of the lighting units. For example, the user may want to have the addresses sequentially increase as the lighting fixtures go from left to right across the face of a building. This may make

5   authoring of lighting sequences easier because the addresses are associated with position or progression.

       Another aspect of the present invention relates to communicating with lighting units and altering their address information. In an embodiment, a lighting unit controller

10   LUC may be associated with several lighting units and the controller may know the address information/identifiers for the lighting units associated with the controller. A user may want to know the relative position of one lighting unit as compared to another and may communicate with the controller to energize a lighting unit such that the user can identify its position within an installation. For example, the user may use a computer

15   with a display to show representations of the controller and the lighting units associated with the controller. The user may select the controller, using the representation on the display, and cause all of the associated lighting units to energize allowing the user to identify their relative or absolute positions. A user may also elect to select a lighting unit address or representation associated with the controller to identify its particular position

20   with the array of other lighting units. The user may repeat this process for all the associated lighting unit addresses to find their relative positions. Then, the user may rearrange the lighting unit representations on the display in an order that is more convenient (e.g. in order of the lighting unit's actual relative positions such as left to right). Information relating to the rearrangement may then be used to facilitate future

25   communications with the lighting units. For example, the information may be communicated to the controller and the lighting units to generate new 'working' addresses for the lighting units that correspond with the re-arrangement. In another embodiment, the information may be stored in a configuration file to facilitate the proper communication to the lighting units.

30

In embodiments a method of determining/compiling mapping information relating to the physical locations of lighting units is provided that includes steps of providing a display system; providing a representation of a first and second lighting unit wherein the representations are associated with a first address; providing a user interface

5   wherein a user can select a lighting unit and cause the selected lighting units to energize; selecting a lighting unit to identify its position and repeating this step for the other lighting unit; re-arranging the representations of the first lighting unit and the second lighting unit on the display using a user interface; and communicating information to the lighting units relating to the rearrangement to set new system addresses. The method

10   may include other steps such as storing information relating to the re-arrangement of the representations on a storage medium. The storage medium may be any electronic storage medium such as a hard drive; CD; DVD; portable memory system or other memory device. The method may also include the step of storing the address information in a lighting unit as the lighting unit working address.

15

In various embodiments, once the lighting units have been identified, the lighting unit controller may transmit the address information to a computer system. The computer system may include a display (e.g., a graphics user interface) where a representation of the lighting unit controller is displayed as an object. The display may

20   also provide representations of the lighting unit 102 as an object. In an embodiment, the computer, possibly through a user interface, may be used to re-arrange the order of the lighting unit representations. For example, a user may click on the lighting unit representation and all of the lighting units associated with the lighting unit controller may energize to provide the user with a physical interpretation of the placement of the

25   lighting unit (e.g. they are located on above the window on the 72nd floor of the building). Then, the user may click on individual lighting unit representations to identify the physical location of the lighting unit within the array of lighting units. As the user identifies the lighting unit locations, the user may rearrange the lighting unit representations on the computer screen such that they represent the ordering in the

30   physical layout. In an embodiment, this information may be stored to a storage medium. The information may also be used in a configuration file such that future

communications with the lighting units are directed per the configuration file. In an

embodiment, information relating to the rearrangement may be transmitted to the

lighting unit controller and new 'working' addresses may be assigned to the individual

lighting units. This may be useful in providing a known configuration of lighting unit

5   addresses to make the authoring of lighting shows and effects easier.

Another aspect of the present invention relates to systems and methods of

communicating to large-scale networks of lighting units. In an embodiment, the

communication to the lighting units originates from a central controller where

10   information is communicated in high level commands to lighting unit controllers. The

high level commands are then interpreted by the lighting unit controllers, and the lighting

unit controllers generate lighting unit commands. In an embodiment, the lighting unit

controller may include its own address such that commands can be directed to the

associated lighting units through controller-addressed information. For example, the

15   central controller may communicate light controller addressed information that contains

instructions for a particular lighting effect. The lighting unit controller may monitor a

network for its own address and once heard, read the associated information. The

information may direct the lighting unit controller to generate a dynamic lighting effect

(e.g. a moving rainbow of colors) and then communicate control signals to its associated

20   lighting units to effectuate the lighting effect. In an embodiment, the lighting unit

controller may also include group address information. For example, it may include a

universe address that associates the controller with other controllers or systems to create

a universe of controllers that can be addressed as a group; or it may include a broadcast

address such that broadcast commands can be sent to all controllers on the network.

25

Referring to Fig. 41, a flow diagram 3900 includes steps for a mapping facility

5002. A mapping facility 5002 can first discover what interfaces are located on an

associated network, such as Ethernet switches or power-data systems. The mapping

facility can then discover what lights are present. The mapping facility then creates a

30   map layout, using the addresses and locations identified for lights as described above.

The mapping can be a two-dimensional representation of the lighting units 102

associated with the mapping facility 5002. The mapping facility 5002 allows the user to group lights within the mapping, until a mapping is complete.

5   The light system manager 5000 may operate in part on the authoring computer 5010, which may include a mapping facility 5002. The mapping facility 5002 may include a graphical user interface 4212, or management tool, which may assist a user in mapping lighting units to locations. The management tool may include various panes, graphs or tables, each displayed in a window of the management tool. A lights/interfaces pane lists lighting units or lighting unit interfaces that are capable of being managed by

10 the management tool. Interfaces may include power/data supplies (PDS) 1758 for one or more lighting systems, DMX interfaces, DALI interfaces, interfaces for individual lighting units, interfaces for a tile lighting unit, or other suitable interfaces. The interface also includes a groups pane, which lists groups of lighting units that are associated with the management tool, including groups that can be associated with the interfaces selected

15 in the lights/interfaces pane. As described in more detail below, the user can group lighting units into a wide variety of different types of groups, and each group formed by the user can be stored and listed in the groups pane. The interface also includes the layout pane, which includes a layout of individual lighting units for a light system or interface that is selected in the lights/interfaces pane. The layout pane shows a

20 representative geometry of the lighting units associated with the selected interface, such as a rectangular array if the interface is an interface for a rectangular tile light. The layout can be any other configuration, as described in connection with the other figures above. Using the interface 4212, a user can discover lighting systems or interfaces for lighting systems, map the layout of lighting units associated with the lighting system, and

25 create groups of lighting units within the mapping, to facilitate authoring of shows or effects across groups of lights, rather than just individual lights. The grouping of lighting units dramatically simplifies the authoring of complex shows for certain configurations of lighting units.

30   Referring to Fig. 42, the graphical user interface 4212 of the mapping facility 5002 of the authoring computer 5010 can display a map, or it may represent a two- or

three- dimensional space in another way, such as with a coordinate system, such as Cartesian, polar or spherical coordinates. In embodiments, lights in an array, such as a rectangular array, can be represented as elements in a matrix, such as with the lower left corner being represented as the origin (0, 0) and each other light being represented as a

5   coordinate pair (x, y), with x being the number of positions away from the origin in the horizontal direction and y being the number of positions away from the origin in the vertical direction. Thus, the coordinate (3, 4) can indicate a light system three positions away from the origin in the horizontal direction and four positions away from the origin in the vertical direction. Using such a coordinate mapping, it is possible to map

10   addresses of real world lighting systems into a virtual environment, where control signals can be generated and associated geometrically with the lighting systems. With conventional addressable lighting systems, a Cartesian coordinate system may allow for mapping of light system locations to authoring systems for light shows. In other embodiments, three-dimensional representations can be provided to simulate three-

15   dimensional locations of lights in the real world, and object-oriented techniques allow manipulation of the representations in the graphical user interface 4212 to be converted to lighting control signals that reflect what is occurring in the graphical user interface 4212.

20   It may be convenient to map lighting systems in various ways. For example, a rectangular array can be formed by suitably arranging a curvilinear string of lighting units. The string of lighting units may use a serial addressing protocol, such as described in the applications incorporated by reference herein, wherein each lighting unit in the string reads, for example, the last unaltered byte of data in a data stream and alters that

25   byte so that the next lighting unit will read the next byte of data. If the number of lighting units N in a rectangular array of lighting units is known, along with the number of rows in which the lighting units are disposed, then, using a table or similar facility, a conversion can be made from a serial arrangement of lighting units 1 to N to another coordinate system, such as a Cartesian coordinate system. Thus, control signals can be

30   mapped from one system to the other system. Similarly, effects and shows generated for particular configurations can be mapped to new configurations, such as any

configurations that can be created by arranging a string of lighting units, whether the share is rectangular, square, circular, triangular, or has some other geometry. In embodiments, once a coordinate transformation is known for setting out a particular geometry of lights, such as building a two-dimensional geometry with a curvilinear

5   string of lighting units, the transformation can be stored as a table or similar facility in connection with the light management system 5002, so that shows authored using one authoring facility can be converted into shows suitable for that particular geometric arrangement of lighting units using the light management system 5002. The light system composer 5004 can store pre-arranged effects that are suitable for known geometries,

10   such as a color chasing rainbow moving across a tile light with sixteen lighting units in a four-by-four array, a burst effect moving outward from the center of an eight-by-eight array of lighting units, or many others.

       Various other geometrical configurations of lighting units are so widely used as

15   to benefit from the storing of pre-authored coordinate transformations, shows and effects. For example, a rectangular configuration is widely employed in architectural lighting environments, such as to light the perimeter of a rectangular item, such as a space, a room, a hallway, a stage, a table, an elevator, an aisle, a ceiling, a wall, an exterior wall, a sign, a billboard, a machine, a vending machine, a gaming machine, a display, a video

20   screen, a swimming pool, a spa, a walkway, a sidewalk, a track, a roadway, a door, a tile, an item of furniture, a box, a housing, a fence, a railing, a deck, or any other rectangular item. Similarly, a triangular configuration can be created, using a curvilinear string of lighting units, or by placing individual addressable lighting units in the configuration. Again, once the locations of lighting units and the dimensions of the triangle are known,

25   a transformation can be made from one coordinate system to another, and pre-arranged effects and shows can be stored for triangular configurations of any selected number of lighting units. Triangular configurations can be used in many environments, such as for lighting triangular faces or items, such as architectural features, alcoves, tiles, ceilings, floors, doors, appliances, boxes, works of art, or any other triangular items.

30

Lighting units 102 can be placed in the form of a character, number, symbol, logo, design mark, trademark, icon, or other configuration designed to convey information or meaning. The lighting units can be strung in a curvilinear string to achieve any configuration in any dimension. Again, once the locations of the lighting

5   units are known, a conversion can be made between Cartesian (x, y) coordinates and the positions of the lighting units in the string, so that an effect generated using a one coordinate system can be transformed into an effect for the other. Characters such as those mentioned above can be used in signs, on vending machines, on gaming machines, on billboards, on transportation platforms, on buses, on airplanes, on ships, on boats, on

10   automobiles, in theatres, in restaurants, or in any other environment where a user wishes to convey information.

Lighting units can be configured in any arbitrary geometry, not limited to two-dimensional configurations. For example, a string of lighting units can cover two sides

15   of a building. The three-dimensional coordinates (x, y, z) can be converted based on the positions of the individual lighting units in the string. Once a conversion is known between the (x, y, z) coordinates and the string positions of the lighting units, shows authored in Cartesian coordinates, such as for individually addressable lighting units, can be converted to shows for a string of lighting units, or vice versa. Pre-stored shows and

20   effects can be authored for any geometry, whether it is a string or a two- or three-dimensional shape. These include rectangles, squares, triangles, geometric solids, spheres, pyramids, tetrahedrons, polyhedrons, cylinders, boxes and many others, including shapes found in nature, such as those of trees, bushes, hills, or other features.

25   Referring to Fig. 41, a flow diagram 3900 shows various steps that are optionally accomplished using the mapping facility 5002, such as the interface 4212, to map lighting units and interfaces for an environment into maps and layouts on the authoring computer 5010. At a step 3902, the mapping facility 1652 can discover interfaces for lighting systems, such as power/data supplies 1758, tile light interfaces, DMX or DALI

30   interfaces, or other lighting system interfaces, such as those connected by an Ethernet switch. At a step 3904 a user determines whether to add more interfaces, returning to the

step 3902 until all interfaces are discovered. At a step 3908 the user can discover a lighting unit, such as one connected by Ethernet, or one connected to an interface discovered at the step 3902. The lights can be added to the map of lighting units associated with each mapped interface, such as in the lights/interfaces pane of the

5   interface 4212. At a step 3910 the user can determine whether to add more lights, returning to the step 3908 until all lights are discovered. When all interfaces and lights are discovered, the user can map the interfaces and lights, such as using the layout pane of the interface 4212. Standard maps can appear for tiles, strings, arrays, or similar configurations. Once all lights are mapped to locations in the layout pane, a user can

10   create groups of lights at a step 3918, returning from the decision point 3920 to the step 3918 until the user has created all desired groups. The groups appear in the groups pane as they are created. The order of the steps in the flow diagram 3900 can be changed; that is, interfaces and lights can be discovered, maps created, or groups formed, in various orders. Once all interfaces and lights are discovered, maps created and groups formed,

15   the mapping is complete at a step 3922. Many embodiments of a graphical user interface for mapping lights in a software program may be envisioned by one of skill in the art in accordance with this invention.

    Using a mapping facility, light systems can optionally be mapped into separate

20   zones, such as DMX zones. The zones can be separate DMX zones, including zones located in different rooms of a building. The zones can be located in the same location within an environment. In embodiments the environment can be a stage lighting environment.

25   Thus, in various embodiments, the mapping facility allows a user to provide a grouping facility for grouping light systems, wherein grouped light systems respond as a group to control signals. In embodiments the grouping facility comprises a directed graph. In embodiments, the grouping facility comprises a drag and drop user interface. In embodiments, the grouping facility comprises a dragging line interface. The grouping

30   facility can permit grouping of any selected geometry, such as a two-dimensional representation of a three-dimensional space. In embodiments, the grouping facility can

permit grouping as a two-dimensional representation that is mapped to light systems in a three-dimensional space. In embodiments, the grouping facility groups lights into groups of a predetermined conventional configuration, such as a rectangular, two-dimensional array, a square, a curvilinear configuration, a line, an oval, an oval-shaped array, a circle,

5   a circular array, a square, a triangle, a triangular array, a serial configuration, a helix, or a double helix.

Referring to Fig. 42, a light system composer 5004 can be provided, running on the authoring computer 5010, for authoring lighting shows comprised of various lighting

10   effects. The lighting shows can be downloaded to the light system engine 5008, to be executed on lighting units 102. The light system composer 5004 is preferably provided with a graphical user interface 4212, with which a lighting show developer interacts to develop a lighting show for a plurality of lighting units 102 that are mapped to locations through the mapping facility 5002. The user interface 4212 supports the convenient

15   generation of lighting effects, embodying the object-oriented programming approaches described above.

Referring to Fig. 43, the user interface 4212 allows a user to develop shows and effects for associated lighting units 102. The user can select an existing effect by

20   initiating a tab 4052 to highlight that effect. In embodiments, certain standard attributes are associated with all or most effects. Each of those attributes can be represented by a field in the user interface 4050. For example, a name field 4054 can hold the name of the effect, which can be selected by the user. A type field 4058 allows the user to enter a type of effect, which may be a custom type of effect programmed by the user, or may be

25   selected from a set of preprogrammed effect types, such as by clicking on a pull-down menu to choose among effects. For example, in Fig. 43, the type field 4058 for the second listed effect indicates that the selected effect is a color-chasing rainbow. A group field 4060 indicates the group to which a given effect is assigned, such as a group created through the light system manager interface 2550 described above. For example, the

30   group might be the first row of a tile light, or it might be a string of lights disposed in an environment. A priority field 4062 indicates the priority of the effect, so that different

effects can be ranked in their priority. For example, an effect can be given a lower priority, so that if there are conflicting effects for a given group during a given show, the a higher priority effect takes precedence. A start field 4064 allows the user to indicate the starting time for an effect, such as in relation to the starting point of a lighting show.

5 An end field 4068 allows the user to indicate the ending time for the effect, either in relation to the timing of the lighting show or in relation to the timing of the start of the effect. A fade in field 4070 allows the user to create a period during which an effect fades in, rather than changes abruptly. A fade out field 4072 allows the user to fade the effect out, rather than ending it abruptly. For a given selected type of effect, the

10 parameters of the effect can be set in an effects pane 4074. The effects pane 4074 automatically changes, prompting the user to enter data that sets the appropriate parameters for the particular type of effect. A timing pane 4078 allows the user to set timing of an effect, such as relative to the start of a show or relative to the start or end of another effect. Parameters can exist for all or most effects. These include the name

15 4152, the type 4154, the group 4158, the priority 4160, the start time 4162, the end time 4164, the fade in parameter 4168 and the fade out parameter 4170.

Referring to Fig. 44, a set of effects can be linked temporally, rather than being set at fixed times relative to the beginning of a show. For example, a second effect can

20 be linked to the ending of a first effect at a point 4452. Similarly, a third effect might be set to begin at a time that is offset by a fixed amount relative to the beginning of the second effect. With linked timing of effects, a particular effect can be changed, without requiring extensive editing of all of the related effects in a lighting show. Once a series of effects is created, each of them can be linked, and the group can be saved together as a

25 meta effect, which can be executed across one or more groups of lights. Once a user has created meta effects, the user can link them, such as by linking a first meta effect and a second meta effect in time relative to each other. Linking effects and meta effects, a user can script entire shows, or portions of shows. The creation of reusable meta effects can greatly simplify the coding of shows across groups.

30

In embodiments a user can select an animation effect, in which a user can generate an effect using software used to generate a dynamic image, such as Flash 5 computer software offered by Macromedia, Incorporated. Flash 5 is a widely used computer program to generate graphics, images and animations. Other useful products

5   used to generate images include, for example, Adobe Illustrator, Adobe Photoshop, and Adobe LiveMotion.

Referring to Fig. 45, a flow diagram 4500 shows steps for converting computer animation data to lighting control signals. In a light management facility 5000, a map

10   file 4504 is created. A graphics facility 4508 is used to create an animation, which is a sequence 4510 of graphics files. A conversion module 4512 converts the map file and the animation facility, based on linking pixels in the animation facility to lights in the mapping facility. The playback tool 4514 delivers data to light systems 4518, so that the light systems 100 play lighting shows that correspond to the animation effects generated

15   by the animation facility.

Various effects can be created, such as a fractal effect, a random color effect, a sparkle effect, streak effect, sweep effect, white fade effect, XY burst effect, XY spiral effect, and text effect.

20

As seen in connection with the various embodiments of the user interface 4212 and related figures, methods and systems are included herein for providing a light system composer 5004 for allowing a user to author a lighting show using a graphical user interface 4212. The light system composer 5004 includes an effect authoring system for

25   allowing a user to generate a graphical representation of a lighting effect. In embodiments the user can set parameters for a plurality of predefined types of lighting effects, create user-defined effects, link effects to other effects, set timing parameters for effects, generate meta effects, and generate shows comprised of more than one meta effect, including shows that link meta effects.

30

In embodiments, a user may assign an effect to a group of light systems. Many effects can be generated, such as a color chasing rainbow, a cross fade effect, a custom rainbow, a fixed color effect, an animation effect, a fractal effect, a random color effect, a sparkle effect, a streak effect, an X burst effect, an XY spiral effect, and a sweep effect.

In embodiments an effect can be an animation effect. In embodiments the animation effect corresponds to an animation generated by an animation facility. In embodiments the effect is loaded from an animation file. The animation facility can be a flash facility, a multimedia facility, a graphics generator, or a three-dimensional animation facility.

In embodiments the lighting show composer facilitates the creation of meta effects that comprise a plurality of linked effects. In embodiments the lighting show composer generates an XML file containing a lighting show according to a document type definition for an XML parser for a light engine. In embodiments the lighting show composer includes stored effects that are designed to run on a predetermined configuration of lighting systems. In embodiments the user can apply a stored effect to a configuration of lighting systems. In embodiments the light system composer includes a graphical simulation of a lighting effect on a lighting configuration. In embodiments the simulation reflects a parameter set by a user for an effect. In embodiments the light show composer allows synchronization of effects between different groups of lighting systems that are grouped using the grouping facility. In embodiments the lighting show composer includes a wizard for adding a predetermined configuration of light systems to a group and for generating effects that are suitable for the predetermined configuration. In embodiments the configuration is a rectangular array, a string, or another predetermined configuration.

Once a show is downloaded to the light system engine 5008, the light system engine 5008 can execute one or more shows in response to a wide variety of user input. For example, a stored show can be triggered for a lighting unit 102 that is mapped to a particular PDS 1758 associated with a light system engine 5008. There can be a user

interface for triggering shows downloaded on the light system engine 5008. For example, the user interface may be a keypad, with one or more buttons for triggering shows. Each button might trigger a different show, or a given sequence of buttons might trigger a particular show, so that a simple push-button interface can trigger many

5   different shows, depending on the sequence. In embodiments, the light system engine 5008 might be associated with a stage lighting system, so that a lighting operator can trigger pre-scripted lighting shows during a concert or other performance by pushing the button at a predetermined point in the performance.

10   In embodiments, other user interfaces can trigger shows stored on a light system engine 5008, such as a knob, a dial, a button, a touch screen, a serial keypad, a slide mechanism, a switch, a sliding switch, a switch/slide combination, a sensor, a decibel meter, an inclinometer, a thermometer, a anemometer, a barometer, or any other input capable of providing a signal to the light system engine 5008. In embodiments the user

15   interface is the serial keypad, wherein initiating a button on the keypad initiates a show in at least one zone of a lighting system governed by a light system engine connected to the keypad.

Referring to Fig. 46, a flow diagram 4600 indicates steps for object-oriented

20   authoring of lighting shows as associated with other computer programs, such as computer games, three-dimensional simulations, entertainment programs and the like. First, at a step 4602 it is possible to code an object in an application. At a step 4604 it is possible to create instances for the objects. At a step 4608 light a system can add light as an instance to the object in the program. At the step 4610 the system can add a thread to

25   the code of the object-oriented program. At a step 4612 the system can draw an input signal from the thread of the object-oriented program for delivering control signals to a light system 100. By adding light as an instance, lighting control signals can go hand-in-hand with other objects, instances and events that take place in other object-oriented computer programs.

30

Referring to Fig. 47, a light system composer 5004 can be used to generate an effect that has various parameters. The parameters include the name 4752, type 4754, group 4758, priority 4760, start time 4762, end time 4764, fade in 4768 and fade out 4770, as well as other parameters for particular effects.

5

Fig. 2 also illustrates that the lighting unit 102 may be configured to receive one or more signals 122 from one or more other signal sources 8400. In one implementation, the processor 3600 of the lighting unit may use the signal(s), either alone or in combination with other control signals (e.g., signals generated by executing a lighting

10   program, one or more outputs from a user interface, etc.), so as to control one or more of the light sources 300 in a manner similar to that discussed above in connection with the user interface 4908.

Examples of the signal(s) that may be received and processed by the processor

15   3600 include, but are not limited to, one or more audio signals, video signals, power signals, various types of data signals, signals representing information obtained from a network (e.g., the Internet), signals representing some detectable/sensed condition, signals from lighting units, signals consisting of modulated light, etc. In various implementations, the signal source(s) 8400 may be located remotely from the lighting

20   unit 102, or included as a component of the lighting unit. For example, in one embodiment, a signal from one lighting unit 102 could be sent over a network to another lighting unit 102.

Some examples of a signal source 8400 that may be employed in, or used in

25   connection with, the lighting unit 102 of Fig. 2 include any of a variety of sensors 8402 or transducers that generate one or more signals in response to some stimulus. Examples of such sensors include, but are not limited to, various types of environmental condition sensors, such as thermally sensitive (e.g., temperature, infrared) sensors, humidity sensors, motion sensors, photosensors/light sensors (e.g., sensors that are sensitive to one

30   or more particular spectra of electromagnetic radiation), sound or vibration sensors or

other pressure/force transducers (e.g., microphones, piezoelectric devices), and the like.

Additional examples of a signal source 8400 include various metering/detection

5   devices that monitor electrical signals or characteristics (e.g., voltage, current, power,
resistance, capacitance, inductance, etc.) or chemical/biological characteristics (e.g.,
acidity, a presence of one or more particular chemical or biological agents, bacteria, etc.)
and provide one or more signals based on measured values of the signals or
characteristics. Yet other examples of a signal source 8400 include various types of

10   scanners, image recognition systems, voice or other sound recognition systems, artificial
intelligence and robotics systems, and the like.

A signal source 8400 could also be a lighting unit 102, a processor 3600, or any
one of many available signal generating devices, such as media players, MP3 players,

15   computers, DVD players, CD players, television signal sources, camera signal sources,
microphones, speakers, telephones, cellular phones, instant messenger devices, SMS
devices, wireless devices, personal organizer devices, and many others.

Many types of signal source 8400 can be used, for sensing any condition or

20   sending any kind of signal, such as temperature, force, electricity, heat flux, voltage,
current, magnetic field, pitch, roll, yaw, acceleration, rotational forces, wind, turbulence,
flow, pressure, volume, fluid level, optical properties, luminosity, electromagnetic
radiation, radio frequency radiation, sound, acoustic levels, decibels, particulate density,
smoke, pollutant density, positron emissions, light levels, color, color temperature, color

25   saturation, infrared radiation, x-ray radiation, ultraviolet radiation, visible spectrum
radiation, states, logical states, bits, bytes, words, data, symbols, and many others
described herein, described in the documents incorporated by reference herein, and
known to those of ordinary skill in the arts.

30   In embodiments the lighting unit 102 can include a timing feature based on an
astronomical clock, which stores not simply time of day, but also solar time (sunrise,

sunset) and can be used to provide other time measurements such as lunar cycles, tidal patterns and other relative time events (harvest season, holidays, hunting season, fiddler crab season, etc.) In embodiments, using a timing facility, a controller 202 can store data relating to such time-based events and make adjustments to control signals based on

5   them. For example, a lighting unit 102 can allow 'cool' color temperature in the summer and warm color temperatures in the winter.

      In embodiments the sensor 8402 can be a light sensor, and the sensor can provide control of a lighting signal based on a feedback loop, in which an algorithm modifies the

10   lighting control signal based on the lighting conditions measured by the sensor. In embodiments, a closed-loop feedback system can read spectral properties and adjust color rendering index, color temperature, color, intensity, or other lighting characteristics based on user inputs or feedback based on additional ambient light sources to correct or change light output.

15

      A feedback system, whether closed loop or open loop, can be of particular use in rendering white light. Some LEDs, such as those containing amber, can have significant variation in wavelength and intensity over operating regimes. Some LEDs also deteriorate quickly over time. To compensate for the temperature change, a feedback

20   system can use a sensor to measure the forward voltage of the LEDs, which gives a good indication of the temperature at which the LEDs are running. In embodiments the system could measure forward voltage over a string of LEDs rather than the whole fixture and assume an average value. This could be used to predict running temperature of the LED to within a few percent. Lifetime variation would be taken care of through a

25   predictive curve based on experimental data on performance of the lights. Degradation can be addressed through an LED that produces amber or red through another mechanism such as phosphor conversion and does this through a more stable material, die or process. Consequently, CRI could also improve dramatically. That LED plus a bluish white or Red LED then enables a color temperature variable white source with

30   good CRI.

In embodiments a lighting system may coordinate with an external system 8800, such as to trigger lighting shows or effects in response to events of the external system, to coordinate the lighting system with the other system, or the like. External systems 8800 can include other lighting systems 100, entertainment systems, security systems,

5   control systems, information technology systems, servers, computers, personal digital assistants, transportation systems, and many other computer-based systems, including control signals for specific commercial or industrial applications, such as machine vision systems, photographic systems, medical systems, pool systems, spa systems, automotive systems, and many others.

10

A lighting system 100 can be used to produce various effects 9200, including static effects, dynamic effects, meta effects, geometric effects, object-oriented shows and the like. Effects can include illumination effects 9300, where light from a lighting unit 102 illuminates another object, such as a wall, a diffuser, or other object. Illumination

15   effects 9300 include generating white lighting with color-temperature control. Effects can also include direct view effects 9400, where light sources 300 are viewed directly or through another material. Direct view effects include displays, works of art, information effects, and others. Effects can include pixel-like effects, effects that occur along series or strings of lighting units 102, effects that take place on arrays of lighting units 102, and

20   three-dimensional effects.

In various embodiments of the present invention, the lighting unit 102 shown in Fig. 2 may be used alone or together with other similar lighting units in a system of lighting units (e.g., as discussed further below in connection with Fig. 2). Used alone or

25   in combination with other lighting units, the lighting unit 102 may be employed in a variety of applications including, but not limited to, interior or exterior space illumination in general, direct or indirect illumination of objects or spaces, theatrical or other entertainment-based / special effects illumination, decorative illumination, safety-oriented illumination, vehicular illumination, illumination of displays and/or

30   merchandise (e.g. for advertising and/or in retail/consumer environments), combined

illumination and communication systems, etc., as well as for various indication and informational purposes.

Referring to Fig. 48, an effect 9200 can include a symbolic effect, such as a sign
5   1204 disposed on the exterior of a building 4800 or on an interior wall or other object. Such a sign 1204 can be displayed many other places, such as inside a building, on a floor, wall, or ceiling, in a corridor, underwater, submerged in a liquid other than water, or in many other environments. A sign 1204 can consist of a backlit display portion and a configuration, such as of letters, numbers, logos, pictures, or the like. The lighting of
10   the backlit portion and the configuration can be coordinated to provide contrasting colors and various aesthetic effects.

Referring to Fig. 48, an object 4850 is lit by a lighting system 4850. In this case the object 4850 is a three-dimensional object. The object 4850 can also be lit internally,
15   to provide its own illumination. Thus, the object 4850 can include color and color temperature of light as a medium, which can interact with changes in color and color temperature from the lighting system 4850. Fig. 48 depicts a foreground object 4850 and a background 4852, both with lighting units 102. Thus, both the foreground object 4850 and the background 4852 can be illuminated in various colors, intensities or color
20   temperatures. In an embodiment, the illumination of the foreground object 4850 and the background 4852 can be coordinated by a processor 3600, such as to produce complementary illumination. For example, the colors of the two can be coordinated so that the color of the background 4852 is a complementary color to the color of the foreground object 4850, so when the background 4852 is red, the foreground object 4850
25   is green, etc. Any object 4850 in any environment can serve as a foreground object 4850. For example, it might be an item of goods in a retail environment, an art object in a display environment, an emergency object in a safety environment, a tool in a working environment, or the like. For example, if a processor 3600 is part of a safety system, the object 4850 could be a fire extinguisher, and the background 4852 could be the case that
30   holds the extinguisher, so that the extinguisher is illuminated upon a fire alert to make it maximally noticeable to a user. Similarly, by managing the contrast between the

background 4852 and the object 4850, an operator of a retail environment can call attention to the object 4850 to encourage purchasing.

5   In embodiments linear strings or series of lights can embody time-based effects 4854, such as to light a lighting unit 102 in a series when a timed-pulse crosses the location of that lighting unit 102.

Effects can be designed to play on arrays 4860, such as created by strings of lighting units 102 that are arranged in such arrays. Effects can be designed in accordance

10   with target areas 4862 that are lit by lighting units 102, rather than in accordance with the lighting units 102 themselves.

Referring to Fig. 49, effects can be tied to a sensor 8402 that detects motion in proximity to a lighting unit 102. Waving a hand or other object in proximity to the

15   sensor 8402 can trigger shows or effects. Effects can also play out over arrays, such as triangular configurations 9258 and rectangular arrays 9260. Effects can cause shows to play out over such arrays in a wide range of effects, such as a bounce effect 9260. In embodiments a lighting system 9250 illuminates an object 9252. Depending on the color of the object, it may either be highlighted or not based on the color of the illumination.

20   For example, red illumination will highlight a red object, but blue illumination will make the red object appear dark. Systems can produce motion effects 9262 by illuminating in different colors over time, so that different items appear highlighted at different times, such as the wings 9262 of different colors in Fig. 49.

25   Referring to Fig. 50, in embodiments of the methods and systems provided herein, the lighting systems further include disposing at least one such lighting unit on a building 5050. In embodiments the lighting units are disposed in an array on a building. In embodiments the array is configured to facilitate displaying at least one of a number, a word, a letter, a logo, a brand, and a symbol. In embodiments the array is configured to

30   display a light show with time-based effects. In other embodiments lighting units may be disposed on interior walls 5052 to produce such effects.

Lighting systems 100 can be found in a wide range of environments 9600. Referring to Fig. 51, environments 9600 include airline environments 5102 and other transportation environments, home exterior environments 5108, such as decks, patios and

5   walkways, seating environments 5104 such as in airline cabins, buses, boats, theatres, movies, auditoriums and other seating environments, building environments 5110, such as to light a profile of a building, pool and spa environments 5112, cylindrical lighting environments 5114, domed lighting environments 5118 and many others. Referring to Fig. 52, environments 9600 can include airline cabins 5202, bus environments 5204,

10   medical and surgical environments 5208, dressing room environments 5210, retail display environments 5212, cabinet environments 5214, beauty environments 5218, work environments 5220, and under-cabinet environments 5222. Referring to Fig. 53, additional environments 9600 include home entertainment environments 5302, motion picture and other camera environments 5304, recreational environments 5308, such as

15   boating, interior environments 5310, seating environments 5312, railings 5318, stairs 5320 and alcoves 5314. Referring to Fig. 54, environments 9600 can include automobiles 5402, appliances 5404, trees and plants 5408, houses 5410, playing fields and courts 5412, display environments 5414, signage environments 5418, ceiling tiles 5420, signaling environments 5422, marine signaling environments 5424, theatrical

20   environments 5428 and bowling environments 5430. Referring to Fig. 55, other environments 9600 include swimming environments 5502, military and aircraft environments 5504, industrial environments 5508, such as hangars and warehouses, house environments 5520, train environments 5512, automotive environments 5514, such as undercar lightings, fireplace environments 5518 and landscape environments

25   5520.

The various concepts discussed herein may be suitably implemented in a variety of environments involving LED-based light sources, other types of light sources not including LEDs, environments that involve both LEDs and other types of light sources in

30   combination, and environments that involve non-lighting-related devices alone or in combination with various types of light sources.

The combination of white light with light of other colors as light sources for lighting units 102 can offer multi-purpose lights for many commercial and home applications, such as in pools, spas, automobiles, building interiors (commercial and

5   residential), indirect lighting applications, such as alcove lighting, commercial point of purchase lighting, merchandising, toys, beauty, signage, aviation, marine, medical, submarine, space, military, consumer, under cabinet lighting, office furniture, landscape, residential including kitchen, home theater, bathroom, faucets, dining rooms, decks, garage, home office, household products, family rooms, tomb lighting, museums,

10   photography, art applications, and many others.

One environment 9600 is a retail environment. An object might be an item of goods to be sold, such as apparel, accessories, electronics, toys, food, or any other retail item. The lighting units 102 can be controlled to light the object with a desired form of

15   lighting. For example, the right color temperature of white light can render the item in a true color, such as the color that it will appear in daylight. This may be desirable for food items or for apparel items, where color is very significant. In other cases, the lighting units 102 can light the item with a particular color, to draw attention to the items, such as by flashing, by washing the item with a chasing rainbow, or by lighting

20   the item with a distinctive color. In other cases the lighting can indicate data, such as rendering items that are on sale in a particular color, such as green. The lighting can be controlled by a central controller, so that different items are lit in different colors and color temperatures along any timeline selected by the user. Lighting systems can also interact with other computer systems, such as cards or handheld devices of a user. For

25   example, a light can react to a signal from a user's handheld device, to indicate that the particular user is entitled to a discount on the object that is lit in a particular color when the user is in proximity. The lighting units 102 can be combined with various sensors that produce a signal source 8400. For example, an object may be lit differently if the system detects proximity of a shopper.

30

Subjects to be displayed under controlled lighting conditions also appear in other environment, such as entertainment environments, museums, galleries, libraries, homes, workplaces, and the like.

5   In a workplace environment lighting units 102 can be used to light the environment 9600, such as a desk, cubicle, office, workbench, laboratory bench, or similar workplace environment. The lighting systems can provide white and non-white color illumination of various colors, color temperatures, and intensities, so that the systems can be used for conventional illumination as well as for aesthetic, entertainment,

10   or utilitarian effects, such as illuminating workplace objects with preferred illumination conditions, such as for analysis or inspection, presenting light shows or other entertainment effects, or indicating data or status. For example, coupled with a signal source 8400, such as a sensor, the workplace lighting systems could illuminate in a given color or intensity to indicate a data condition, such as speed of a factory line, size of a

15   stock portfolio, outside temperature, presence of a person in an office, whether someone is available to meet, or the like.

In embodiments, lighting systems can include an architectural lighting system, an entertainment lighting system, a restaurant lighting system, a stage lighting system, a

20   theatrical lighting system, a concert lighting system, an arena lighting system, a signage system, a building exterior lighting system, a landscape lighting system, a pool lighting system, a spa lighting system, a transportation lighting system, a marine lighting system, a military lighting system, a stadium lighting system, a motion picture lighting system, photography lighting system, a medical lighting system, a residential lighting system, a

25   studio lighting system, and a television lighting system.

In embodiments of the methods and systems provided herein, the lighting systems can be disposed on a vehicle, an automobile, a boat, a mast, a sail, an airplane, a wing, a fountain, a waterfall or similar item. In other embodiments, lighting units can be

30   disposed on a deck, a stairway, a door, a window, a roofline, a gazebo, a jungle gym, a swing set, a slide, a tree house, a club house, a garage, a shed, a pool, a spa, furniture, an

umbrella, a counter, a cabinet, a pond, a walkway, a tree, a fence, a light pole, a statue or other object.

LED PACKAGE DISCLOSURE

5   Referring to Fig. 56, one form of light source 300 is an LED module 5650. An LED module 5650 may be used as a light source 300 in a wide variety of components, subassemblies, boards 204, products, fixtures, housings 800, applications, methods of use and environments as described in this disclosure. In an embodiment, the LED module 5650 may comprise an LED package with a substrate 5652, one or more LED

10   die 5654 (which, as context permits, may comprise any other light emitting source, such as the light sources 300 described above), a reflector 5658 for reflecting light from the LED die 5654 out from the module 5650, a filler 5660, such as a silicone or injection-molded plastic filler (which may have a hole or space in it to allow more light to pass through), a lens 5662 or other optical facility 400 (which may be any type of optical

15   facility described throughout this disclosure), and one or more leads 5664 for providing an external electrical connection from the module 5650 to other electronic components. In embodiments the reflector 5668 and the components held in the reflector 5668 are positioned on top of the leads 5664. A wire bond 5668 may connect the LED die 5654 to the edge of the reflector 5658. A submount 5670 may include one or more other

20   electronic components for controlling the intensity of light emitted from the LED die 5654 as described below. Thus, the present invention encompasses a light source, such as an LED module, with at least one LED die 5654, and a package for the LED die 5654, the package including a submount 5670, wherein the submount 5670 incorporates an electronic component for controlling the LED, wherein the electronic component

25   facilitates control of at least one of the intensity and the apparent intensity of the LED die between at least three distinct levels of intensity.

           Fig. 57 shows a simple configuration of a conventional LED module 5650, with an ESD protection diode 5770 serving as the submount 5670 in a circuit with the LED

30   die 5654. In embodiments, the submount may be augmented with other electronic components as described below.

Fig. 58 shows another embodiment of an LED module 5650, which like the LED module of Fig. 56 can be used as a light source 300 in a wide variety of components, subassemblies, boards 204, products, fixtures, housings 800, applications, methods of

5   use and environments as described in this disclosure. In this embodiment, the LED module 5650 may again comprise an LED package with a substrate 5652, one or more LED die 5654 (which, as context permits, may comprise any other light emitting source, such as the light sources 300 described above), a reflector 5658 for reflecting light from the LED die 5654 out from the module 5650, a filler 5660, such as a silicone or

10   injection-molded plastic filler (which may have a hole or space in it to allow more light to pass through), a lens 5662 or other optical facility 400 (which may be any type of optical facility described throughout this disclosure), and one or more leads 5664 for providing an external electrical connection from the module 5650 to other electronic components. In this case one of the leads 5664 may connect to the side of the reflector

15   5658. The entire package may include an injection molding 5850, such as injection-molded plastic, for holding the components in place. A wire bond 5668 may connect the LED die 5654 to the edge of the reflector 5658. A submount 5670 may include one or more other electronic components for controlling the intensity of light emitted from the LED die 5654 as described below. In this case the submount 5670, rather than being

20   located directly under the LED die 5654 and the reflector 5658, is located in close proximity to the reflector cup on the substrate 5652 and is in electrical connection to the LED die 5654.

Fig. 59 shows another embodiment of an LED module 5650, which like the LED

25   modules of Figs. 56 and 58 can be used as a light source 300 in a wide variety of components, subassemblies, boards 204, products, fixtures, housings 800, applications, methods of use and environments as described in this disclosure. In this embodiment, the LED module 5650 may again comprise an LED package with a substrate 5652, one or more LED die 5654 (which, as context permits, may comprise any other light emitting

30   source, such as the light sources 300 described above), a reflector 5658 for reflecting light from the LED die 5654 out from the module 5650, a filler 5660, such as a silicone

or injection-molded plastic filler (which may have a hole or space in it to allow more light to pass through), a plastic encasing element 5950, a lens 5662 or other optical facility 400 (which may be any type of optical facility described throughout this disclosure), and one or more leads 5664 for providing an external electrical connection

5   from the module 5650 to other electronic components. In this case the leads 5664 may connect to the side of the reflector 5658. As in other embodiments, a wire bond 5668 may connect the LED die 5654 to the edge of the reflector 5658. A submount 5670 may include one or more other electronic components for controlling the intensity of light emitted from the LED die 5654 as described below. In this case the submount 5670,

10   rather than being located directly under the LED die 5654 and the reflector 5658, is located in the cup of the reflector 5658 with the LED die 5654. In embodiments the LED module 5650 may be made by a mask process.

Other embodiments of LED packages that include an LED die 5654 and a

15   submount 5670 may be understood by those of ordinary skill in the art and are encompassed herein. In embodiments the LED die 5654 may be is a high-power LED die. In embodiments the LED die 5654 may be a five watt or greater LED die.

The substrate 5652 of the embodiments of Figs. 56, 58 and 59 may be any

20   conventional substrate for an LED package, such as a metal core substrate, a ceramic substrate, a ceramic on metal substrate, an FR4 substrate, a sapphire substrate, a silicon on sapphire substrate, or a silicon carbide substrate.

In the various embodiments described herein, an LED 5654 may be controlled by

25   the electronic components of the submount 5770. In addition to offering basic "on" and "off" or protection circuitry, in embodiments of the inventions electronic components located in the submount 5670 that is integrated with the LED 5654 in the package 5650 can control the intensity or apparent intensity of light coming from the LED 5654, such as by controlling the level of current to the LED, by controlling the amplitude of pulses

30   or current to the LED (pulse amplitude modulation), by controlling the width of pulses of current to the LED (pulse width modulation) or by a combination of any of the

foregoing. Thus, the various embodiments described herein for providing such control can be embodied in the submount 5670, such as in packages of the types disclosed in connection with Figs. 56, 58 and 59 and other embodiments described herein, such as described in connection with Figs. 25a, 25b, and 25c, among others.

5

Referring to Fig. 60, a schematic diagram is provided that shows a submount 5670 and a group of LED dies 5654 in a package 5650. It should be understood that the submount 5670 could be combined with a single LED die 5654, and that the submount 5670 and LED die(s) 5654 could be integrated into a variety of physical packages, such

10   as those described in connection with Figs. 56, 58 and 59, or other LED packages 5650 of various configurations that include a submount 5670 and LED die(s) 5654. Thus, the schematic diagrams of Fig. 60 and subsequent figures are intended to encompass any of the various physical packages 5650 that can include the components disclosed in connection with such figures.

15

Fig. 60 shows an LED package where the submount 5670 includes a current regulator 6052. The current regulator 6052 may be any current regulation component, such as for taking in a DC signal 6054. In embodiments, the current regulator 6052 located in the submount 5670 allows the LED package to take a direct twelve volt DC

20   signal 6054 without requiring any components that are external to the LED package 5650.

Fig. 61 shows an LED package 5650 where the submount 5670 includes a circuit 6152 for taking an alternating current signal, such as a twelve-volt AC signal 6154,

25   directly. The circuit may include a bridge rectifier, a capacitor, a current regulator, and/or other circuit elements for converting an AC signal into an input suitable for delivery to an LED die 5654. In embodiments the circuit 6152 can take an AC signal with voltage in a range of voltages, such as a range from 100V to 240V, or a range from 12V to 240V. The circuit 6152 can include any suitable components for taking an AC

30   signal 6154 and converting the signal to control the intensity or apparent intensity of the

LED die(s) 5654. Examples of such circuits include those disclosed throughout this disclosure and other known to those of ordinary skill in the art.

Referring to Fig. 62, in embodiments the submount 5670 may include one or more electronic components, such as a circuit 6252, for accepting either an AC signal 6154 or a DC signal 6054. The components may include those similar to those described in connection with Figs. 60 and 61, as well as other suitable components for accepting AC and DC signals. In embodiments, the component 6252 may comprise a switch mode power supply and/or a current regulator, so that the LED package 5650 can accept either AC power or DC power directly, without requiring a separate power supply or other component, and the LED package 5650 can convert the AC or DC power into a suitable signal for controlling the intensity or apparent intensity of the LED die(s) 5654. Embodiments such as the one depicted in the schematic diagram of Fig. 62 offer the substantial convenience of allowing users to connect LED packages 5650 to various types of power without requiring separate power supplies. In embodiments, the LED package 5650 may include an interface for switching the power supply between modes, such as an AC mode, a DC mode, or a selected voltage. The interface may include an optional resistor that can be placed in circuit with the LED package 5650, such as to alter the incoming voltage, or it may include a signal, such as a signal to cause a circuit or component of the LED package 5650 to regulate itself, such as to change modes.

Referring to Fig. 63, in embodiments the submount 5670 may include a circuit 6352, such as a circuit for controlling the current or voltage delivered to the LED package 5650, such as through any of the techniques described herein. In an embodiment, the circuit 6352 may be a circuit or other electronic component that is configured to receive an input signal from a conventional electrical component, such as an electrical power circuit that includes a dimmer. Thus, as the input signal is dimmed or increased in intensity, the circuit 6352 may respond by changing the signal sent to the LED die(s) 5654, to change the apparent intensity of the LED die(s) to correspond in a way that is proportionate, or related to, the signal sent from the dimmer circuit, such as by changing the pulse width and/or pulse amplitude of the signals sent to the LED die(s).

The circuit 6352 may take the form of various dimmer compatible control circuits described in applications and patent incorporated by reference herein, as well as other dimmer-compatible circuits 6352. In embodiments the circuit 6352 may be a drive circuit adapted to receive an arbitrary voltage and to control the LED die(s) 5654 in

5   response to different voltages without requiring other components.

Referring to Fig. 64, in embodiments the LED package 5650 may include one or more electronic components 6452, such as components 6452 configured to respond to events related to the incoming power signal. For example, the components 6452 may

10   include various stored control modes for controlling the signals sent to the LED die(s) 5654, such as stored control modes for generating specific sequences, such as shows and effects, from the LED die(s) 5654, including any of the effects described in this disclosure. The stored modes can be triggered, for example, by a power cycle event 6454. For example, turning on or off the power can change the mode of the component

15   6454, such as to allow a user to cycle through a series of different modes of the LED package 5650 by repeatedly switching power on or off, or by otherwise altering the incoming power signal 6454. Power cycle control components and circuits can take various forms, including those described in the applications and patent incorporated by reference herein and disclosed elsewhere in this disclosure, including in connection with

20   Fig. 25.

Referring to Fig. 65, in embodiments the submount 5670 may include an electronic component that includes a data interface 6552 for receiving an incoming data signal 6554. For example, the data interface may be configured to receive a lighting

25   control signal, such as used in connection with any conventional lighting units, including LED-based lighting units as described in this disclosure and in the patents and applications incorporated by reference herein. For example, the data interface 6552 may be configured to receive a data signal 6554 that is a DMX signal, a DALI signal, an Ethernet signal, a TCP/IP protocol signal, an HTTP protocol signal, an XML or other

30   mark-up language instruction, a script, an 802.11 or other wireless signal, a cellular or radio-frequency signal, an infrared signal, a Bluetooth signal or any other kind of wired

or wireless data signal. The data interface 6552 may include a processor, memory, and/or one or more suitable circuit elements for receiving and responding to data, such as to trigger stored programs to be executed as lighting signals from the LED die(s) 5654 or to control the LED die(s) 5654 in response to the signals. Embodiments may include

5   circuits such as disclosed in connection with Figs. 28 and 31b of this disclosure, as well as other interface circuits known to those of ordinary skill in the art. In embodiments the submount 5670 may include various firmware components. In embodiments the firmware may include a data interface 6552, such as an XML parser or other data interface as described herein.

10

Referring to Fig. 66, in embodiments the submount 5670 may include an application specific integrated circuit, or ASIC 6652. The ASIC 6652 may be configured to respond to an incoming signal 6654, which may be a signal configured according to a protocol that is suitable to be read by the ASIC 6652. In various embodiments, an ASIC

15   6652 may perform any of a wide variety of processes and functions.

In embodiments the ASIC 6652 may respond to signals 6654 according to a serial addressing protocol, such as described in connection with Fig. 31a above and in the documents incorporated by reference herein. For example, in embodiments the ASIC

20   6652 may receive an incoming data signal 6654 that is comprised of a series of bytes. The ASIC 6652 may respond to the first byte of the data signal that does is unmodified, such as by checking each byte in the series and responding to the first bit that does not contain a "1". The ASIC may control the LED die(s) 5654 based on the first byte that does not contain the "1", such as by causing the LED die(s) 5654 to emit light at an

25   intensity or apparent intensity based on the information contained in that byte. The ASIC 6652 can then alter the first bit of the byte to which it responded by inserting a "1" in that bit and relay the data signal on to another similar LED package 5650 or lighting unit 102 that contains a similar ASIC, so that the next ASIC responds to the next byte of the data signal, i.e., the first remaining unmodified byte of the signal. With such a

30   protocol, a series of LED packages 5650 can respond to a simple data signal that includes all instructions in a serial protocol. Other ASICs 6652 can be designed and

included in the submount 5670 for controlling LED die(s) 5654, as may be envisioned by those of ordinary skill in the art.

In embodiments the LED packages 5650 disclosed throughout this disclosure may be incorporated into displays, such as a graphics display, a monitor, a video display, 5 or an animation display, such as a large-scale display for display on a wall, building, or the like. In embodiments such a display may include a string of nodes, each of which includes an LED package 5650, with each package including an ASIC 6652 on the submount 5670. The ASIC 6652 may be configured to receive a video signal in various formats, including a video signal delivered according to a serial addressing protocol.
10

Referring to Fig. 67, the submount 5670 may include a processor 3600 among other electronic components for controlling a signal to the LED die(s) 5654. The processor 3600 may have any of the attributes described above, such as the capability to respond to power-cycle events, power/data signals as described in connection with Fig. 15 16a, Fig. 18 and Fig. 24, data, network signals, and other signals. The processor 3600 can support various control capabilities, such as feed forward capabilities 4100, pulse width and pulse amplitude modulation, such as described in connection with Figs. 25a, 25b and 25c, voltage regulation, current regulation, power mode selection, inductive loop capabilities 4200, response to dimming signals, response to signal sources 8400, 20 response to sensors, addressing capabilities 6600, calibration capabilities, control facilities 3500, drive facilities 3800, power factor control facilities, such as described in connection with Fig. 15, high voltage facilities, such as described in connection with Figs. 16b and 17, data facilities 3700, and other capabilities, all as described herein and in the patents, applications and other documents incorporated by reference herein or as 25 known by those of ordinary skill in the art. In embodiments the processor 3600 can select between a pulse-width-modulation mode and a pulse-amplitude-modulation mode. In embodiments the processor 3600 can be configured to respond to signal sources 8400 of a wide variety, as described above in connection with the description of Fig. 2. In embodiments the processor 3600 may be a microcontroller. In embodiments the 30 processor 3600 may allow the LED package 5650 to respond to power signals delivered at any arbitrary voltage.

Referring to Fig. 68, in embodiments the submount 5670 may include a circuit or other component 6852, which is responsive to an input signal 6854 from a sensor, which may be any kind of sensor or signal source 8400 described above. Thus, an LED

.5   package 5650 can be made directly responsive to sensors, such as temperature sensors (such as to preserve lifetime of the LED die(s) 5654 under adverse thermal conditions), photosensors (such as to aid in calibrating light coming from the LED die(s) 5654), motion sensors, sound sensors, and other kinds of sensors and transducers, without requiring additional control circuitry. In embodiments the sensor may be integrated as

10   part of the submount 5670, or it may be external to the LED package 5650 and provide an input signal to a sensor-responsive circuit or other component in the submount 5670. In embodiments the LED package 5650 may be incorporated into an illumination system that responds to sensors. In other embodiments, the LED package 5650 may be incorporated into an indicator device, such as an indicator light to indicate a sensed

15   condition. Thus, an LED package 5650 may be respond to any signal source or sensor described herein such as the operating state of a device, the operating state of a sensor, or a sensed condition, such as acceleration, pressure, temperature, time, humidity, light, a fault condition, proximity, or a chemical condition.

20   Referring to Fig. 69, in embodiments the submount 5670 may include one or more components for providing power-factor-control 6952. The power-factor-control circuit may be a circuit similar to the ones described in connection with Fig. 15 above or in other patents, applications and documents incorporated by reference herein. The power-factor-control circuit 6952 may take incoming power 6954, such as from AC or

25   DC line voltage, and convert it to a form suitable for driving the LED die(s) 5654, without requiring other external components.

Referring to Fig. 70, in embodiments the submount 5670 may include an inductive loop drive circuit 7052 in response to an input signal 7054, such as for

30   inductively driving the LED die(s) 5654 as described in certain patent applications and documents incorporated herein by reference.

Referring to Fig. 71, in embodiments the submount 5670 may include a feed-forward drive circuit 7152 in response to an input signal 7154, such as for driving the LED die(s) 5654 with a feed-forward facility 4100 as described elsewhere herein and in

5   certain patent applications and documents incorporated herein by reference.

Referring to Fig. 72, in embodiments the submount 5670 may include a power/data facility 7252 in response to an input combined power/data signal 7254, such as for driving the LED die(s) 5654 with a power/data facility as described elsewhere

10   herein in connection with Figs. 16a, 18 and 24, as well as in certain patent applications and documents incorporated herein by reference.

Referring to Fig. 73, in embodiments the submount 5670 may include a timing facility 7352 that allows the LED package 5650 to respond to timing signals 7354 or that

15   may generate an internal timing signal to generate light from the LED package 5650 according to predetermined timing requirements, such as for shows stored in memory 3700 or controlled by a processor 3600, as described elsewhere herein and in certain patent applications and documents incorporated herein by reference.

20   Referring to Fig. 74, in embodiments the submount 5670 may include a circuit 7452 for responding to a high-voltage input 7454, such as for driving the LED die(s) 5654 with a high-voltage facility as described herein in connection with Fig.16b and Fig. 17 and in certain patent applications and documents incorporated herein by reference.

25   Referring to Fig. 75, in embodiments the submount 5670 may include a data facility 3700, such as memory 3700, for storing programs and/or data, such as for responding to an input signal 7454, such as for driving the LED die(s) 5654 in intelligent response to the input signal 7554. A data storage facility 3700 may include a look-up table, stored program modes, programs for responding to control signals, programs for

30   responding to data according to various protocols, protocols for responding to signal sources 8400, including sensors, calibration programs, addressing programs, programs

for executing shows and effects, or other data storage capabilities as described herein and in certain patent applications and documents incorporated herein by reference.   In embodiments the memory 3700 may include a stored program for controlling power to the LED die 5654 based on the anticipated requirements of the installation of the LED

5   package 5650. In embodiments the memory 3700 may be EPROM.   In embodiments the memory 3700 may be DRAM, SRAM, or other RAM.

Referring to Fig. 76, in embodiments the submount 5670 may include a digital-to-analog converter 7652, such as for converting an incoming digital signal 7654 to an analog signal, such as to be relayed to drive the LED die(s) 5654. Alternatively, a

10   submount could also include an analog-to-digital converter in conjunction with other components, such as to take an incoming analog signal and convert it to a digital signal for further processing before a control signal is relayed to the LED die(s) 5654.

15   Referring to Fig. 77, in embodiments the submount 5670 may include a bridge rectifier, such as for rectifying an incoming signal 7754, such as to be relayed to drive the LED die(s) 5654.

Referring to Fig. 78, in embodiments the submount 5670 may include a boost

20   converter, such as for converting an incoming signal 7854, such as to be relayed to drive the LED die(s) 5654.

Referring to Fig. 79, in embodiments the submount 5670 may include a boost regulator, such as for regulating an incoming signal 7954, such as to be relayed to drive

25   the LED die(s) 5654.

Referring to Fig. 80, in embodiments the submount 5670 may include multiple components 8052, 8054, such as to respond to multiple input signals 8058, 8060. The components 8052, 8054 can be any of the circuits or other components described herein,

30   including those described in connection with Figs. 60 through 79.

Referring to Fig. 81, a submount 5670 may include a component 8152 for receiving an incoming signal 8154 from an electrically conductive element 8158, such as a bus, wire, track, or other element. In embodiments the LED package 5650 can be snapped into such a conductive element 8158 for easy assembly of lighting units 102 that

5   include LED packages 5650.

Lighting units 102 that include LED packages 5650 such as disclosed in connection with Figs. 56 through 81 may be used in a variety of products, components, subassemblies, fixtures, products, systems, applications, and environments to produce a

10   wide variety of shows and effects, including those described throughout this disclosure. For example, the LED packages 5650 can be used as a camera flash unit, a boat light, in an MR-type lighting fixture, or in various other products.

In embodiments the LED package 5650 may be provided with other elements,

15   such as a user interface for programming the LED package. For example, the LED package 5650 could be provided with a set of resistors, where each resistor, when placed in series with the LED package 5650, adjusts the control signal to the LED package 5650 to operate in a different mode, or wherein the resistor or other user interface assists in identifying the type of LED package 5650 that is being used, such as to assist in

20   addressing control signals to the LED package 5650.

Referring to Fig. 82, in embodiments the submount 5670 of the LED package 5650 may include a thermal facility 8252 for cooling at least one of the LED die(s) and the submount 5670. The thermal facility may be any thermal facility 2500 as described

25   above. In embodiments the thermal facility 8252 may be a Peltier effect device, a fluid cooling facility 8268, such as for cooling the submount 5670 with water or another cooling fluid, a potting facility 8264, such as for surrounding the submount 5670 and accepting heat from the submount 5670 or the LED die 5654, a thermally conductive plate 8258 or gap pad, such as for conducting heat away from the submount 5670, a

30   micro-machine, such as a MEMs device 8260 fabricated from nano-materials and, for